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ERTS-1 IMAGERY AS AN AID TO THE DEFINITION OF THE GEOTECTONIC DOMAINS OF THE SOUTHERN AFRICAN CRYSTALLINE SHIELD

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ABSTRACT

The ancient granite-greenstone cratons and the metamorphic mobile belts are two major geotectonic units of the Southern African Crystalline Shield. Each has its own distinctive structural style. The cratons are characterised by arcuate vulcano-sedimentary belts encircling or partially encircling diapirically intrusive gneissic tonalitic batholiths. These rocks, with their well defined structural imprint, are sharply transgressed by younger, more potash-rich granites. The metamorphic mobile belts, on the other hand, are characterised by paragneisses and other high grade metamorphites. Plastic flowage folding phenomena involving complex refolding and the development of basin and dome structures are the most diagnostic features.

Portions of these two geotectonic environments have been studied on ERTS-1 imagery. It was found that the broad synoptic view provided by this imagery is ideally suited to a study of the diagnostic macrostructures, and that the different geotectonic styles are clearly recorded. ERTS-1 imagery thus allows a more accurate definition than exists at present of the contact zones and internal structures of the two domains. The importance of this investigation as an aid to gaining on insight into the relevance of plate tectonics in Precambrian times is briefly discussed.

1. INTRODUCTION.

The main objective of the present study has been the identification and documentation of the important large scale features which characterise and therefore identify the major geotectonic environments of the Southern African crystalline shield. The two main geological domains recognised are the ancient, so-called granite-greenstone cratonic nuclei and the younger encircling metamorphic mobile belts. The study to date has involved the examination of ERTS-1 colour composite imagery covering portions of these environments (Figure 1). It is hoped at a later stage to extend the study so as to define the full extent of the important contact zone between the cratonic nuclei and the metamorphic mobile belts as well as to study the internal structures and lithologies of these two environments in more detail. It is envisaged that important data relating to the relevance of plate tectonics in Precambrian times should emerge from this study.

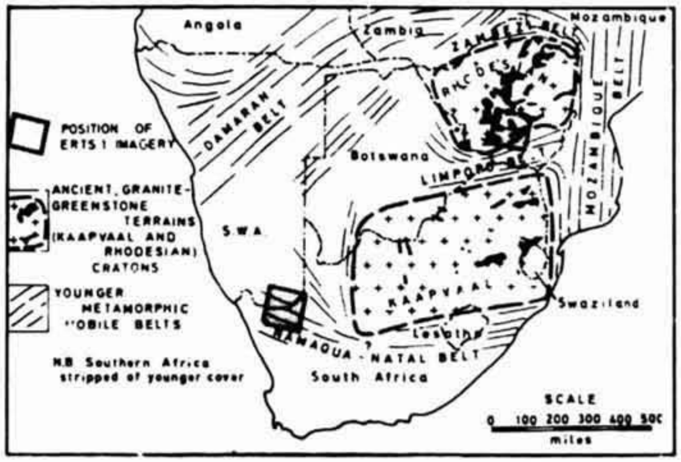

Figure 1. The Southern African Crystalline Shield showing the main geotectonic domains and the areas covered by the ERTS-1 images discussed in this paper.

2. THE GRANITE-GREENSTONE CRATONS.

Archaean granite-greenstone terrains often constitute the most ancient and stable portions of the continents and appear to be reamrkably similar in all of the better known shield areas of the world. Vulcano-sedimentary sequences known as greenstone belts are the most distinctive features of these terrains and represent the remnants of previously more extensive accumulations of volcanic and sedimentary rocks. The greenstone belts in their present form appear to "float" in the form of deformed synclinal "keels" or"rafts" in complex granite terrains.

Despite their great age such belts have not been subjected to high grades of thermal metamorphism and primary volcanic and sedimentary structures are commonly encountered. Most belts have been subjected to strong structural deformation which is responsible for their characteristic form. Narrow arcuate schist belts trending at various angles from the main belt are particularly important as are large-scale isoclinal folds with axes more or less parallel to the regional grain of the belt. The typical granite greenstone pattern showing in particular the arcuate synclinal schist slivers is depicted in figure 2.

The lowermost volcanic assemblage of most greenstone belts commences with a suite of ultramafic and related rocks, intermediate to acid tuffs and magnesium-rich basalts. Some of the ultramafics represent subaqueous peridotite lavas while others form part of layered intrusive ultramafic complexes. The lowermost volcanic succession is overlain largely by metatholeiitic basalts (greenstones) with narrow interlayers of acid lava and chert. Shales, greywackes and quartzites form the uppermost stratigraphic assemblages of most belts.

Several different types of granitic rock each with its own tectonic style, petrology and chemistry are generally present. The oldest are invariably gneisses of tonalitic composition, and often intrude the lowermost volcanics in the form of diapiric domes. The arcuate schist belts tend to drape around these domes and are responsible for the distinctive greenstone pattern noted in (Fig. 2). The tonalitic gneisses often give rise to low-lying featureless country.

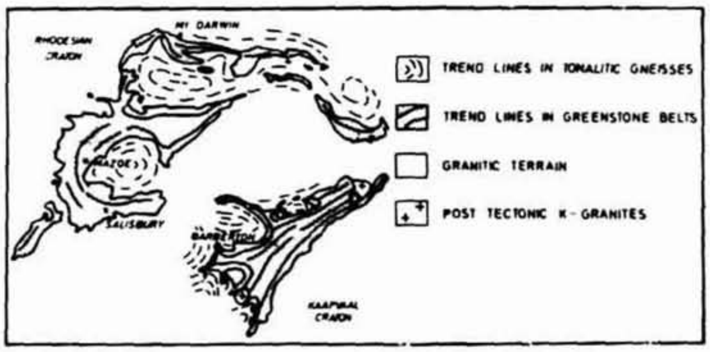

Figure 2. Typical granite-greenstone pattern showing arcuate greenstones draped around tonalitic domes. Note younger cross cutting potassium-rich granites Examples from the Rhodesian and Kaapvaal cratons of Southern Africa.

Younger more potassium-rich granite plutons cause abrupt truncation of earlier formed structures and fabrics both in the older gneisses and in the greenstone belts. They are generally more resistant to erosion and give rise to the higher lying ground or boulder-strewn hills.

3. THE METAMORPHIC MOBILE BELT ENVIRONMENT.

Surrounding and dividing the cratonic nuclei are a series of metamorphic mobile belts. Such belts are essentially linear zones containing high grade, granitized metamorphic tectonites which show abundant evidence of rheid flow and plastic flowage folding. This can lead to the production of a complex pattern of re-folded folds in a continuous sequence of deformation as shown in figure 3 which depicts an area from the Namaqualand mobile belt of the Cape Province of South Africa. Major linear zones of transcurrent dislocation are common, particularly along the marginal zones of the mobile belts and there is usually evidence of repeated fault movement. From the above and from a comparison of figures 2 and 3 it is clear that the major structures typical of mobile belts are very different from those encountered in greenstone belts and they reflect fundamental differences in the geotectonic setting of these two environments.

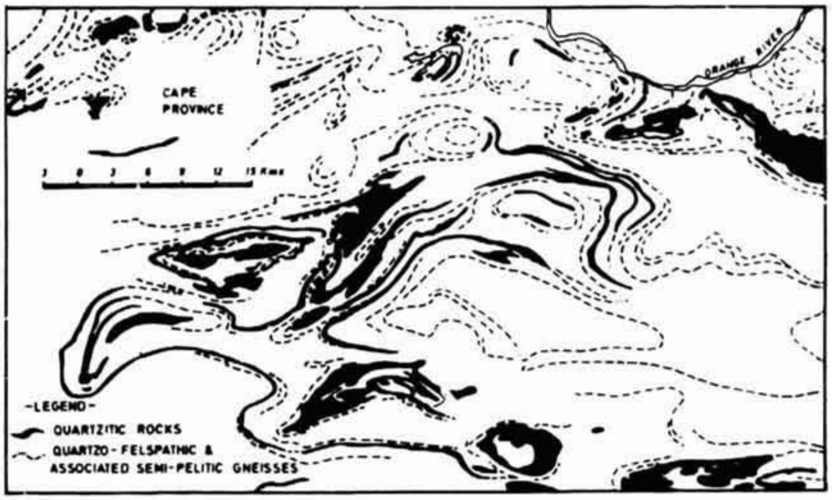

Figure 3. Typical metamorphic mobile belt pattern showing complex flowage folding phenomena of a high grade metamorphic assemblage.

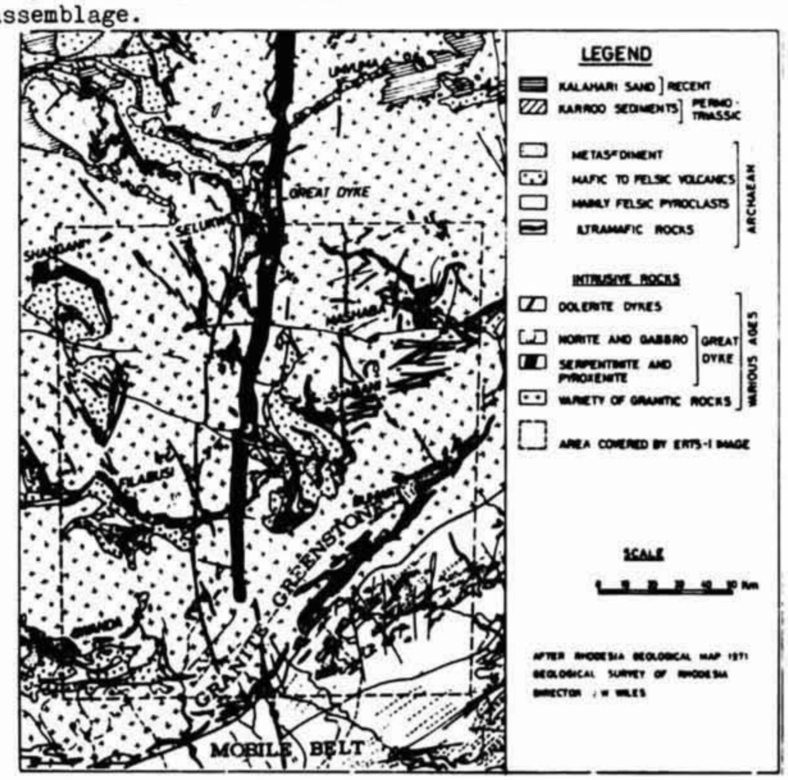

Figure 4. Geological m·p of part of the Rhodesian craton and the north marginal ᷊one of the Limpopo belt.

4. <u>ERTS-1 IMAGERY AS AN AID TO THE IDENTIFICATION OF THE DISTINCTIVE PATTERNS OF THE CRYSTALLINE SHIELD</u>

a) <u>THE GRANITE-GREENSTONE ENVIRONMENT</u>.

ERTS-1 image No. 1103-07291 covers part of the southern sector of the Rhodesian craton and portion of the linear north marginal zone of the Limpopo mobile belt (Fig. 1). The available 1:1,000,000 geological survey map of this and surrounding areas is shown in figure 4. Most of the greenstone belts have been mapped but much of the granite terrain including the geology of the mobile belt is poorly understood with available data being mainly of a photogeological nature.

Figure 5 shows the ERTS image covering this area and the geological interpretation. The Great Dyke traverses the central part of the image and is the most clearly defined feature. The bulk of the Dyke is ultramafic in nature (grey blue on colour composite and dark grey on black and white prints but contains very well defined (heavily vegetated) layers and canoe shaped remnants of gabbro which give an exceptionally clear view of the internal structure of the body.

All the features of the granite-greenstone environment are clearly visible. These include the arcuate schist belt slivers which are strike-ing features in the case of the Buhwa, Gwanda and Filabusi belts. Certain of the stratigraphic components of the greenstone belts are also distinguishable, particularly in the case of the Shangani belt where the lowermost stratigraphic assemblage comprised of resistant layered ultra-mafic bodies and some banded ironstones forms a resistant zone flanking the eastern margin of the belt. This zone clearly distinguished by dark grey colour tones can be traced southwards where it appears to split, one branch trending westwards and the other southeastwards where it constitutes the northern flank of the Filabusi belt. The Shabani and Mashaba ultramafic complexes are clearly visible and the waste dumps from asbestos mining operations are conspicuous. The younger intrusive nature of the Mashaba ultramafic body is clearly demons-trated by the western limb which is superimposed on a north-south stratigraphy consisting of greenstone belt slivers lying within tonalitic gneisses.

In all cases the internal structure (mainly folding)and the gross stratigraphy of the greenstone belts is discernable. In addition all the major mines in the area are clearly recognised by their waste dumps.

The distinctive geotectonic styles of the various cratonic granites are also to be seen. The generally featureless terrain which gives rise to lighter colour tones is underlain by the tonalitic gneiss assemblage. Arcuate greenstone-belt tongues protrude into this terrain and probably define or partly define individual diapiric tonalitic batholiths. Numerous cross-cutting potassium-rich granite bodies occur in the area and as a result of their somewhat more resistant and jointed nature have greater water holding properties. This has resulted in more luxuriant plant growth which clearly defines such bodies, particularly on colour composite prints.

Figure 5. Photogeological interpretation of ERTS-1 image No. 1103-07291 showing part of the southern region of the Rhodesian craton and the north marginal zone of the Limpopo belt.

The most well defined of these bodies intrudes the Shangani belt causing abrupt truncation of all the stratigraphic trends. In addition several other similar but somewhat smaller bodies are also discernable in the western sector of the image. An extensive and as ye unmapped elongated zone of potassium-rich granite has recently been identified by the Rhodesian Geological Survey in the zone between the Shabani and Buhwa greenstone belts. The contacts of this granite (termed the Chibi batholith), which might be a marginal manifestation of the Limpopo metamorphic mobile belt can be remarkable accurately mapped from the image. The body is characterised by a spectacular joint and /or fault system normal to the contact of the mobile belt. The jointing has lead to the development of numerous component granite domes which are surrounded by thick vegetation.

Besides the Great Dyke two narrow but well defined parallel satellite dykes are also conspicuous features of the image. These together with a number of other dykes which are also clearly seen give a good indication of the type and extent of faulting which has affected the entire area. All the major east-west trending faults appear to have right lateral movement.

b) <u>THE MOBILE METAMORPHIC BELT ENVIRONMENT</u>.

Part of the north marginal zone of the Limpopo mobile belt occupies the S.E. part of the image No. 1103-07291. Although lacking the large scale flowage folding features, present only in the central zone of the belt, the distinctive linear grain, tonal difference, and absence of arcuate forms readily distinguishes this terrain from the granite-greenstone terrain to the north.

The strong linearity of trends along the north margin is due to tectonic overprinting in the form of shearing and major transcurrent dislocation, probably just after the formation of syntectonic eutectoid granites one of which can be defined on the image.

As an example of the more typical flowage folding pattern of the mobile belts, ERTS image No. 1055-08053 covering part of the Namaqualand belt along the Orange river in the N.W. Cape Province and southern S.W.A., has been studied as part of this investigation. A few unpublished maps of a small part of this area are available and the interpretation presented in thus based largely on the ERTS image (Fig. 6).

The typical flowage folding pattern with the development of intricate fold structures in the form of cross folds, "eye" folds etc. is clearly a widespread phenomenon of the area studied. Most of the rocks are paragneisses with amphibolitic material becoming important towards the N.E. A quartzitic assemblage which splits into two ranges occurs in the southern portion of the area and is of considerable economic importance because of recent significant base metal finds. The extensions and distribution of this zone, not defined before, are readily apparent from the ERTS imagery due to the resistant nature of the quartzite ridges. In addition a major zone of dislocation with right lateral movement and not known to exist previously, is a dominant feature of the central portion of the image. Three gabbroic intrusions appear to be closely associated with this zone and nickel/copper mineralisation has been located in one of these. Tantalum-bearing pegmatites are also present within the same zone which therefore appears to have acted as the locus for a variety of mineral deposits.

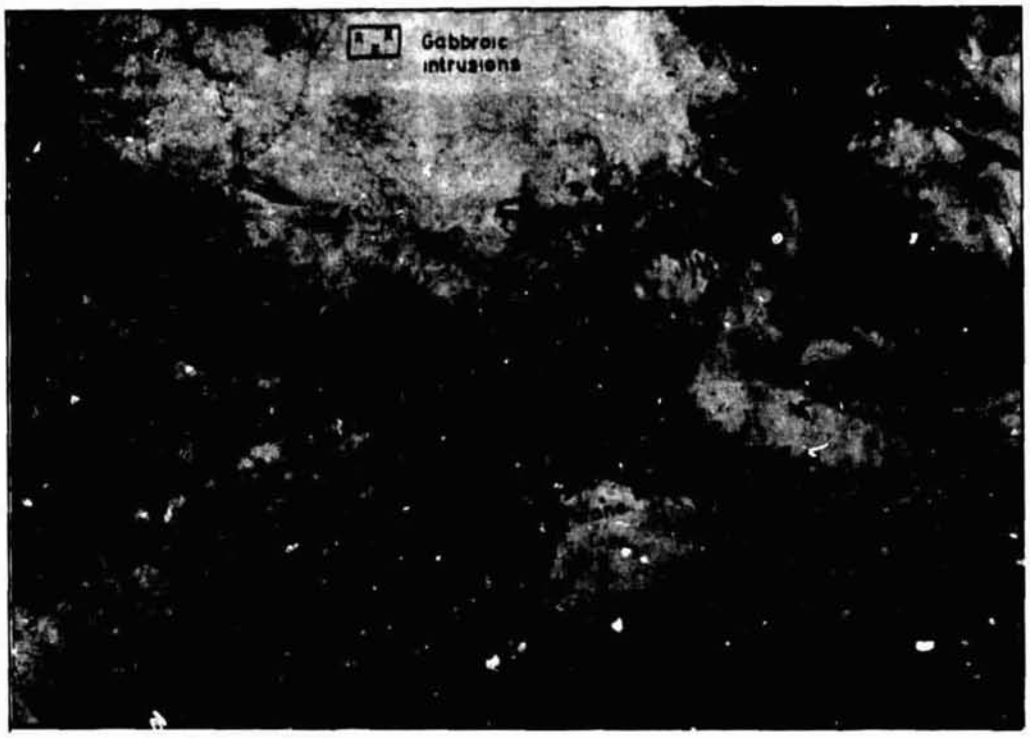

Figure 6. Portion of ERTS-1 image No. 1055-08053 of the N.W. Cape showing typical flowage folding pattern of the metamorphic mobile environment.

5. SUMMARY AND CONCLUSIONS.

It is the writer's opinion that the broad synoptic view provided by the imagery is ideally suited to a study of the diagnostic macro-structures of the two geotectonic domains considered in this paper. ERTS-1 imagery should allow for a better understanding and more accurate definition than exists at present of the contact zones of these two geologic environments. This may be of considerable economic importance, since basic/ultrabasic rocks containing some of the world's largest nickel deposits have been emplaced along similar contact regions within the Canadian Shield. These include the Thompson belt deposits at the junction of the Superior Craton with the Churchill mobile belt and the Sudbury nickel irruptive lying within the contact region of the Grenville front (mobile belt) and the Superior granite-greenstone province.

Initial results warrant a more detailed study and form the basis of proposal submitted for the ERTS-B programme. The proposal involves a study of the granite-greenstone cratons and encircling mobile belts with a view to gaining an insight into the relevance of plate tectonics in Precambrian times. It has been suggested that the mobile metamorphic belts could represent the root zones of mountain systems and therefore, the sites of possible subduction zones for plates of early Archaean earth crust. The greenstone belts have often been equated with island arc systems and as such could themselves represent ancient subduction zones. A study of the continuity of lithologies, gravity and magnetic data etc. from craton into the mobile belt will be an important part of the study together with a search for features which might have represented ancient transform faults.

6. ACKNOWLEDGEMENTS.

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