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GROWTH AND DECLINE OF VEGETATION ON MINE DUMPS

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Abstract

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1. INTRODUCTION

This report has been prepared as a "Type I report" in accordance with section 3, paragraph C of the "Provisions for Participation in the NASA Earth Resources Technology Satellite - A (ERTS-A) Project." As such it is a record of progress made on ERTS investigation SR-577. This is the second type 1 report to be submitted.

In section 2 we present a signigicant result regarding geological applications of ERTS data which was identified by Professor D.A. Pretorius of

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Sections 3 to 9 describe progress on the official investigation SR-577.

PART A : SIGNIFICANT RESULTS

2. SIGNIFICANT RESULTS

TITLE : A Structural Interpretation of the Gravity Field Over the Gordonia-Carnarvon Region of the Northern Cape Province

AUTHOR : Prof. D.A. Pretorius

CATEGORY : 3 JKA

As part of a study of the crustal structure of Southern Africa, the gravity field was re-investigated over a region covering 220 000 sq.km. between Witdraai in the northwest, Kuruman in the northeast, Middelburg in the southeast, and Fraserburg in the southwest. From the 1958 Bouguer anomaly map of the Geological Survey of South Africa, 491 gravity stations were selected for a polynomial trend surface analysis aimed at decomposing the total Bouguer anomalies into a regional component and a local deviation.

The most conspicuous pattern on all the residual maps is the discontinuity in gravity trends along a NW-NNW line which coincides approximately with the western limit of the main development of Kaaien quartzites between Copperton in the southeast and Upington in the northwest.

The interpretation of the processed gravity field has been studied in the light of information available from ERTS-1 imagery. The central part of the region investigated is covered by images 1053-07540 and 1053-07542, obtained in September, 1972. There is a striking correlation between the gravity trends and the lineaments clearly visible on the two images. In particular, the Brakbos fault zone is most conspicuous. A well-defined, intense pattern of sinuous lineaments terminates abruptly against a pattern with a minimum of very broad lineaments only. To the east of the line of truncation, the general strike of the lineaments is NNE, while to the east the general strike is NNW. As the Brakbos fault zone is approached, the lineaments from the NNE become progressively more deformed about fold axes trending NNW. The intensity of deformation associated with the fault zone is most conspicuous on the images. The

ERTS-1 imagery proves beyond doubt that the junction between the Kaapvaal craton and the Namaqualand metamorphic terrain is not along the Doornberg lineament, but along the Brakbos fault zone about 35 kms to the west. The continuation of both the Doornberg and Brakbos lineaments beneath the Paleozoic Karroo cover is readily discernible.

Had the imagery become available three or four years earlier, it would not have required the reprocessing of the gravity field to delineate one of the major structural features of South Africa. The images would also have been of appreciable value in the initial stages of the current prospecting programmes for base metals in the Prieska-Upington area. The Brakbos lineament can now be seen to represent the loci for the known mineralization at Copperton and Areachap. An extensive tract of country between these two localities can be seen, on the ERTS-1 imagery, to be underlain by potentially favourable loci for further mineralization.

PART B : REPORT ON ERTS-1 PROJECT NUMBER SR-0577

3. OBJECTIVES OF PROJECT

(a) To determine whether ERTS imagery can be used to distinguish mine dumps with vegetative cover from mine dumps without vegetative cover at 3 monthly intervals throughout the year.

(b) To ascertain whether the percentage of mine dump area that is covered by vegetation can be determined at 3 monthly intervals throughout the year.

4. SUMMARY OF ACCOMPLISHMENTS DURING REPORTING PERIOD

4.1 An aircraft overflight to gather large scale imagery has been carried out over selected mine dumps.

4.2 As was outlined in the previous type II report, an attempt has now been made to radiometrically relate mine dump densities on ERTS imagery with mine dump radiances calculated from in situ spectroradiometric measurements. The results have been dissappointing and are reported on in appendix A.

4.3 Insufficient new ERTS-1 imagery has been received to investigate the existance of a seasonal trend.

4.4 A computer program has been written to read CCT's and data processing to improve radiometric correlation with ground truth is anticipated.

5. SUMMARY OF ACCOMPLISHMENTS PLANNED FOR NEXT REPORTING PERIOD

5.1 More detailed interpretative work is planned to ascertain whether a seasonal trend in mine dump vegetative cover is evident.

5.2 More intensive work using CCT's and the new "linear density transparencies" is planned to establish a radiometric relationship between the density on ERTS imagery and ground scene radiances. Without the successful generation of such a relationship all results will be suspect.

6. DESCRIPTIONS OF MAJOR PROBLEMS ENCOUNTERED

Two major problems have been encountered.

6.1 As anticipated in the original ERTS-A proposal to NASA, the non-uniformity of vegetative cover on the mine dumps results in different densities being recorded depending upon the exact location on the mine dump image where the measurement is carried out. This requires that the ground truth information should be significantly improved, and attempts in this direction are presently being made.

6.2 We have been unable to establish a quantitative radiometric relationship between the mine dump densities on ERTS-1 transparencies and mine dump radiances calculated from field spectral reflectance measurements. A report on the relevant calculations appears in appendix A. It is thought that the lack of agreement is due to the mine dumps (which are, generally speaking, high radiance objects) being exposed during EBR processing so as to fall on the shoulder of the NASA negatives (or toe of the positives). It is hoped that the use of CCT's or "high radiance transparencies" will overcome this problem.

7. DISCUSSION OF SIGNIFICANT RESULTS

7.1 No significant results have been obtained on the official mine dump vegetation program SR-0577.

7.2 A significant result has been obtained by Prof. D.A. Pretorius of

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who is to act as co-investigator on proposal No. 29520 prepared for the ERTS-B project. This significant result is herewith reported (see section 2) to NASA with the full approval of Prof. Pretorius. A summary of the paper appears as appendix B.

8. CHANGES IN OPERATING PROCEDURE

No changes are planned except as described in section 5 above.

9. LIST OF PUBLISHED ARTICLES AN/OR PAPERS, REPORTS ETC., RELEASED DURING REPORTING PERIOD

None.

APPENDIX A

As a prelude to quantitatively categorizing mine dump vegetation status, reflected radiance values from in situ reflectance data and MSS image density readings were compared. The three classes of reflectors on the dump surface were slime exposure, short grasses, and mesophytic plant canopies. By estimating their reflectance contributions on a percent coverage basis within an MSS resolution element, it was hoped that careful densitometry would yield quantitative vegetative cover categories from the MSS imagery.

A pointwise numerical integration of reflected radiance over the respective bandpasses of the four MSS channels was carried out using equation (1).

$$\Phi = \frac{1}{\pi}\int_{\lambda_1}^{\lambda_2} \rho(\lambda).\tau(\lambda).\left[L_s(\lambda)\cos\theta_s + L'_s\right]d\lambda \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

The bivariate reflectance $\rho(\lambda)$, of each of the three reflector classes was thus integrated over the effective bandwidth, λ_1 to λ_2 of each MSS channel (responsivity $\tau(\lambda)$) in turn to give the data shown in table 1. Direct, L_s, and indirect, L'_s, local solar irradiance data (Kok, 1972) were corrected for the time of imagery exposure using the solar elevation value θ_s, given in the MSS image annotation.

From the data of report No. 73/6 (a supplementary report submitted to NASA), the bivariate reflectances of target 3 (Eragrostis curvula), target 5 (100% slime exposure), and target 10 (Acacia Cyclopis) were taken as representative of the slime, short grasses, and mesophytic plant canopy classes respectively.

TABLE 1

BAND	REFLECTED RADIANCE FROM MINE DUMP SURFACE ELEMENT		
	Slime Exposure ($\mu W\ cm^{-2}\ sr^{-1}$)	Short grasses ($\mu w\ cm^{-2}\ sr^{-1}$)	Mesophytic plant canopy ($\mu w\ cm^{-2}\ sr^{-1}$)
4	1,8	0,4	0,2
5	1,4	0,3	0,1
6	1,3	0,4	0,6
7	1,3	0,6	1,2

Using NASA frame 1175-07303, enlargements (approximately 13X) were made of the mine dump area and calibration wedge. Several dumps of known vegetative cover were selected and their MSS image densities in the four channels measured together with the densities of the fourteen step calibration wedge. By interpolating the transmittance values for the imaged dumps with those of the wedge, the proportion of the "maximum specified radiance" and hence absolute radiance value, (Table G.2-2, ERTS Data Users Handbook) was calculated for each measured image. These radiances for the selected dumps are shown in table 2.

B

TABLE 2

DUMP	STATUS OF VEGETATION	BAND	APPROX. RADIANCE ($\mu w\ cm^{-2}\ sr^{-1}$)
5/L/29	0	4	2,0
	0	5	1,7
	0	6	1,45
	0	7	3,2
1/A/20	5	4	0,85
	5	5	0,7
	5	6	0,6
	5	7	1,6
7/L/1 West Side	4	4	0,95
	4	5	0,8
	4	6	0,7
	4	7	2,25
1/L/40	4	4	0,95
	4	5	0,8
	4	6	0,75
	4	7	1,9

A comparison of radiances calculated from ground truth and sensor imagery show a number of anomalies. Although the slime of dump 5/L/29 correlates well in bands 4, 5 and 6, band 7 gives a factor of 2,5 greater radiance than is apparent from the ground data. Similar radiance values in bands 6 and 7 should have be recorded for all dumps of table 1 as they were predominantly covered with short grasses with varying amounts of slime exposure. This was not the case, however and band 6 gave anomalously low values throughout.

The sensor recorded apparent radiances of 1/A/20 are lower in all bands than those of 1/L/40. These two dumps are in close proximity and have a similar vegetation type (short grasses). Dump 1/L/40 has partial slime exposure within its grass cover and the greater reflectance of the slime compared with the grass was exhibited by the increased reflected radiance. A general observation of qualitative significance is the trend of decreasing sensor radiances for bands 5 and 6 with increasing grass cover. Dump 7/L/1 (west side) has benefited from extensive irrigation since the inception of this vegetation monitoring program. This healthy condition is exhibited by the increased band 7 radiance over 1/L/40 whereas radiances in other bands are almost identical.

It is recognised that atmospheric effects may have a significant influence on the reflected radiances as seen by the sensor. Other complications could have arisen from the small image size of the mine dumps and the possibility that due to slime surfaces having a comparatively high radiance, they have been exposed so as to fall on the "shoulder" of the NASA negative (or toe of the positive). The radiometric correlation is therefore tentative at this stage and requires further analysis before the quantitive data can be applied to mine dump vegetative categories. It is anticipated, however, that analysis of MSS CCT's will yield more accurate radiometric data as errors introduced by photographic processing will be absent.

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Spectral irradiance of daylight at Pretoria
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APPENDIX B

A Structural Interpretation of the Gravity Field Over the Gordonia-Carnarvon Region of the Northern Cape Province

(Summary of paper presented on 9 April, 1973, at the Congress of the Geological Society of South Africa, held in Bloemfontein, Orange Free State, South Africa)

This work was carried out by Prof. D.A. Pretorius
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Republic of South Africa

who is to act as co-investigator on the project prepared for the ERTS-B program, and is herewith reported to NASA with his approval.

As part of a study of the crustal structure of Southern Africa, the gravity field was re-investigated over a region covering 220 000 sq.km. between Witdraai in the northwest, Kuruman in the northeast, Middelburg in the southeast, and Fraserburg in the southwest. From the 1958 Bouguer anomaly map of the Geological Survey of South Africa, 491 gravity stations were selected for a polynomial trend surface analysis aimed at decomposing the total Bouguer anomalies into a regional component and a local deviation. The average intensity of observation was one gravimetric station per sq.km. Surfaces and residuals up to the sixth order were computed. The region examined is of considerable structural interest, straddling the metamorphic terrain stretching from the Richtersveld, through Namaqualand, and Bushmanland to the Kakamas-Kenhardt-Upington-Prieska area, and the exposed apparent southwestern termination of the Kaapvaal craton.

The linear regional component has a north-northwesterly strike, and the values increase from -120 milligals in the east of the region studies to -80 milligals in the west. This pattern is believed to be influenced mainly by the NW-NNW fabric of the pre-Ventersdorp Sequence basement along the Orange River, west of the Doringberg fault zone. The increase in gravity is interpreted as being the product of a thicker sialic crust over the Kaapvaal craton in the east and a thinner granitoid crust under the metamorphic terrain in the west.

The higher-order surfaces, particularly the sixth, are dominated by the Strondkop gravity high, one of the most conspicuous regional gravity features in South Africa. This gravity high is centred in the east-central part of Gordonia, northeast of Upington and west of Olifantshoek. The regional component attains a maximum of less than -80 milligals which is 50 milligals higher than the regional gravity low in the Kimberley-Colesberg area. The main contributor to the Strondkop regional gravity high is the Groenwater positive anomaly, a most conspicuous high, arcuate in shape, extending for 300 km from Black Rock in the north, through Olifantshoek, to the Eselberge on the Orange River in the Southwest. Hales and Gough (1962) called this feature the Northwest Cape isostatic anomaly. Although it is present in the general vicinity of the substantial iron formations of the Transvaal Sequence, which run through Sishen, they belived that the anomaly was too large to be accounted for by these strata. They suggested that the anomaly might be caused by a body, denser than normal crustal material, lying at a depth of less than 20 km and with a thickness of between 5 000 and 9 000 metres.

The most conspicuous pattern on all the residual maps is the discontinuity in gravity trends along a NW-NNW line which coincides approximately with the western limit of the main development of Kaaien quartzites between Copperton in the southeast and Upington in the northwest. The line has been interpreted as a fault zone - named the Brakbos fault zone - which can be traced for at least 500 km. Paucity of gravity observations between Upington and Witdraai do not permit the positive identification of the continuation of the line of discontinuities, but it is believed that the fault zone persists at least as far as the South West African border. The presence of the fault zone is easily decipherable beneath the cover of the Karroo Sequence southeast of Copperton, and the Brakbos structure is still strongly developed between Carnarvon and Vosburg, the southern limit of the present investigation. The displacement is apparently right-lateral, but it is believed that the zone is composed of normal faults with a downthrouw on the northeastern side. The Doringberg lineament parallels the Brakbos fault zone, to the east, but it would now appear that the Brakbos lineament is more rightly the boundary between the Kaapvaal craton and the Namaqualand metamorphic terrain.

The interpretation of the processed gravity field has been studied in the light of information available from ERTS-1 imagery. The central part of the region investigated is covered by Images 1053-07540 and 1053-07542, obtained in September, 1972. There is a striking correlation between the gravity trends and the lineaments clearly visible on the two images. In particular, the Brakbos fault zone is most conspicuous. A well-defined, intense pattern of sinuous lineaments terminates abruptly against a pattern with a minimum of very broad lineaments only. To the east of the line of truncation, the general strike of the lineaments is NNE, while to the west the general strike is NNW. As the Brakbos fault zone is approached, the lineaments from the NNE become progressively more deformed about fold axes trending NNW. The intensity of deformation associated with the fault zone is most conspicuous on the images. The ERTS-1 imagery proves beyond doubt that the junction between the Kaapvaal craton and the Namaqualand metamorphic terraine is not along the Doornberg lineament, but along the Brakbos fault zone about 35 kms. to the west. The continuation of both the Doornberg and Brakbos lineaments beneath the Paleozoic Karroo cover is readily discernible.

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