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REPORT ON A VISIT TO ZAMBIA
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1.0 Introduction

The purpose of this visit was:

To examine and update the current WB project satellite image data base in the Geological Survey Department (GSD), Lusaka

To geometrically correct Landsat TM satellite data to the Zambia National map projection and interactively process data for enhancement of geological and geomorphological features

To process and output to hard copy new data in support of the EU cartography project

To validate satellite image features in selected field areas in east and northeast Zambia

2.0 Diary

27/28 September	Keyworth-London-Harare
28 September	Harare-Lusaka
29 September	Geological Survey Department: Meet Director, Mr. D. Mulela. Meet C. Murray, EU project cartographer.
30 October	GSD. Review data base on PC and carry out back up operations
1 October	GSD. Further back up and data transfer from CD.
2 October	GSD. Processing of data: Muyombe area, NE Zambia
3 October	Meeting with BGS staff, Wallingford and Czech Geological Survey Geologists
4 October	GSD. Data extraction and processing
5 October	GSD. Extract and enhance data of Mwinilunga project area, NW Zambia
6 October	GSD. Resampling of Muyombe TM data to Transverse Mercator Projection
7 October	GSD. Resampling experiments on eastern half of East Zambia project TM data
8 October	GSD. Utilise results of resampled data to effect image to image registration of western half of East Zambia project data. Extraction of Chikwa subset data and enhancement for geological features
9 October	Free
10 October	GSD. Extraction and enhancement of South Luangwa data set; output to tape
11-13 October	GSD. Geological interpretation of Katete TM imagery; discussion with C. Murray. Plotting of Muyombe, Chikwa and South Luangwa data subsets.
14 October	Lusaka – Chipata
15 October	Chipata – Lundazi – Manga Camp

16 October Manga Camp 17 October Manga – Muyombe – Matenda River Flying camp
18 – 23 October Field Traversing west and north of Matenda River
24 October Camp. Plot data and interpret TM image of Muyombe area
25 October Reconnaissance along track: Chitepu to Thendele
26 – 30 October Field traversing in the Muyalela, Chanama and Kabundi River areas
30 October Kabundi – Isoka – Serenje
31 October Serenje – Lusaka
1 – 4 November GSD, Lusaka. Write report and collate project data
4 – 5 November Lusaka – Harare – London – Keyworth

3.0 Data processing

Existing data on the Compaq PC dedicated to image analysis using Erdas Imagine V 8.3.1 was reviewed and, where appropriate, backed up and labeled on DAT 4 mm tape archives.

3.1 Georeferencing of data

The current georeferenced Landsat TM data covering the project areas in eastern and north-western Zambia has been found to be unsatisfactory in terms of accurate location of GPS data points (waypoints). This is attributed to the utilisation of the UTM projection system and Clarke 1880 Spheroid and Datum which is distinct from the standard Transverse Mercator map projection and Zambia 1950 Arc Datum used for the construction of topographic maps in Zambia. Experiments were carried out on the Muyombe TM data subset collecting coordinate ground control points from 1: 50 000 scale topographic maps and registering these to the corresponding TM pixel sites. This was done using the Raster-Geometric Correction – Polynomial Geocorrection Model - Transformation (Level 1) utility in Erdas Imagine. The control points are saved to Ground Control Point (GCP) files and when the lowest order of the RMS Error is obtained for a representative spread of points, the data are then resampled to the chosen Map Projection and output pixel size of choice (30 x 30 metres). A test of the output data revealed that GPS points are plotting with greater accuracy on data registered to TM projection, Clarke 1880 Spheroid and Zambia 1950 Arc Datum. Further experiments carried out included the resampling of the eastern and western sectors of Landsat TM data using the image to image registration facility. Plotting accuracy of GPS data points has been significantly improved following tests of the data. It is recommended that the raw TM data for both project areas, held at Keyworth, be resampled to this Map Projection using the satellite-derived ground control coordinates supplied in the header file.

3.2 Data Enhancement

Several data enhancement options were assessed to increase geological discrimination of structures and possible lithologies. Various band combinations were tested and one of the most informative appears to be the 5, 3 and 1 composite which excludes the main vegetation indicator of band 4. Other useful tools included decorrelation stretch which maximises differences between otherwise highly correlated data bands. Principal Components also perform a similar function but the resultant colour renditions are difficult to interpret. The mineral composite function which is a band ratio combination of B5/7, B5/4 and B3/1 is actually a type of vegetation discriminator in the case of forested Savannah in southern Africa but can be useful in areas of natural vegetation to yield clues of soil patterns controlled by variations in bedrock. The Band 5, 3 and 1 composite was the simplest and most informative enhancement tool combined with filtering and contrast stretch modifications. This function was applied to the Muyombe, Chikwa and South Luangwa TM subscenes and converted to TIF format for loading into MapInfo. The MapInfo files were then sent to a DJ plotter for hard copy output.

A 6 band subset of raw TM data covering the Makutu Hills area within the Muyombe mapping subproject was extracted from CD Rom to a laptop and used for demonstration purposes to Zambian counterparts in the field.

4.0 Field verification

The Muyombe area has not previously been geologically mapped by the GSD or other organisation. The writer made a reconnaissance visit to the area in September, 1998 as part of a regional orientation and training programme for two Zambian counterpart geologists.
This area is one of high relief mountain chains; the Makutu and Mafingi Ranges in the western sector and the Vipama Range in the east. The intervening ground is marked by individual prominent hills whilst in the southern sector flattish to undulating ground dips southward toward the Chire River valley. The region is well drained and many small streams and rivers draining the Makutu Hills, in particular, contain flowing water throughout the dry season. Although the high mountainous areas are still relatively covered by woodland, a substantial encroachment in the valleys and foothills by slash and burn farmers has denuded much of this forest.

The geology of the area gleaned from the above cited visit and a recent reconnaissance visit by Czech and BGS geologists identified a suite of hill-forming basic to intermediate coarse grained granulites and gneissic granulites of probable Ubendian age. These rocks, occurring mostly in the central area, are replaced further north by a coarse grained pink feldspar porphryroblastic biotite rich granite and melacratic ?charnockite and both rock types are covered/overprinted by a NNE-trending range of quartzites and phyllites in the Makutu Hills correlated with the Mafingi Group of Irumide age in the North (Fitches, 1971). Sediments of Karroo age with a distinctive hogback geomorphology and vegetation pattern outcrop in the southern sector.

The TM imagery indicates the presence of two dissected erosion surfaces; one older unit developed on ?granites in the Lusanga River area in the north and a second younger surface occupying the central median ground around Muyombe and southward. A geological interpretation of the Muyombe TM image further shows three sets of geomorphic linears; an E-W set which corresponds to ductile shears and may act as lithological boundaries within the granulite unit, A NNE set marking the resistant quartzites and related lithologies of the Makutu Group which locally demonstrate tight to isoclinal folds distended by shearing in the axial zones. Other smaller linears show a divergent ENE trend away from the main range. The third set is a EW to ENE–trending array of linears in unnamed mountain ranges dissected by the Manga and Kabundi Rivers within the Fungwe Forest area. N-S trending linears occur north of the Makutu Hills trend in the Chanama District and Muyalela River areas. The western edge of these mountainous tracts is marked by an abrupt N-S trending escarpment attributed to Irumide age Mafingi Hills structures and post-Karroo faulting and this trend is mirrored by N-S trending valley-forming fractures or fault linears within the mountain zone.

5.0 Geology

Field traversing in the eastern flank of the Makutu mountains and the Fungwe National Forest area (Sheet SC-36-11) has confirmed the presence of a general lithostratigraphic sequence of older mela and mesocratic biotite-rich granulites intruded by a distinctive kfeldspar-porphyroblastic biotite-rich granite of possible Ubendian age (2300 - 1800 Ma). These are overlain by and structurally interleaved with a sequence of white orthoquartzites and mica schists of the Makutu Hills Group correlated with Irumide age (1350-950 Ma, after Ring 1993.) metasediments of the Mafingi Hills in the north (Fitches, 1971).

5.1 Structures

The structural relationships within and between Ubendian age rocks and the Makutu metasediments is complex and comprises a packet of E-W ductile shearing in granulites and granites accompanied by a steep to shallow stretching mineral lineation which transforms these crystalline rocks to micaceous haematitic porphyroclastic phyllonites; this set is strongly overprinted by a mainly N-S trending wide shear zone which entrains both Makutu metasediments and underlying granulites and granite into micaceous phyllites and mylonites associated with tight isoclinal folds in quartzite bands displayed in the crestal mountain zones on the satellite imagery. This type of folding is further evidenced by frequent changes in dip direction in phyllites and quartzites of the Makutu and transitional Makutu-Ubendian schistose rocks. The intense N-S shearing of probable Irumide age has caused local rotation of the E-W Ubendian-age shearing into subparallelism with Makutu trends. The N-S shearing event is accompanied by splitting and interslicing of Makutu and Ubendian lithologies, particularly in the eastern flanks of the Makutu range.

5.2 Lithostratigraphy

5.2.1 Granulites

The granulites are dark to light grey, coarse grained biotite-rich, with possible cordierite, garnet and locally sillimanite, bluish to honey-coloured quartz and plagioclase; mafic varieties may contain pyroxene and amphibole. The rocks are generally granoblastic and often display a banded or streaky gneissic texture which seems to be discernible on a macroscopic scale locally on granulite hill features. North of Muyumbe the granulites are transformed by shearing to chlorite, biotite quartz mylonites.

5.2.2 Ntendele Granite

Granite lithologies provisionally referred to as the Ntendele Granite (after the granite hills adjacent to the Ntendele school) are of two main types: melacratic biotite-rich and mesocratic Kfeldspar porphyroblastic. The biotite-rich variety with up to 15% biotite are melacratic medium grained with brown to honey-coloured quartz. plagioclase and a varied amount of small pink Kfeldspars which rank it as a granodiorite. Some dark coarse grained types exposed in the Muyalela River Valley may have pyroxene and amphibole which suggest a possible charnockitic origin. Most of this granite has been affected by some degree of shearing or foliation structure. The porphyroblastic variety is a very distinctive type with large (up to 10 by 4 cm and averaging 3 by 2 cm) megacrystals of twinned Kfeldspar mostly oriented along the foliation planes but they frequently grow across and deform the biotite fabric. The matrix is mela to mesocratic and biotite rich similar to the first granite type described. The Ntendele granite is probably a hybrid granite originating as a ?charnockitic granite and was converted to granodiorite/mozogranite type by progressive replacemnet of potash feldspar. Concordant pink aplite dykes and gray microgranite (granodiorite) veins are also present. The porphyroblastic type is well developed in the prominent hills drained by the Muyalela River in the central Fungwe Forest area.

5.2.3 Foliated granite

Strongly foliated mesocratic granites are prominent in the hills drained by the Kabundi River in the south Fungwe Forest. Two types of this metagranite are also found: a melacratic biotite-rich type with a variable Kfeldspar content granodiorite and a leucocratic blue-brown quartz-feldspar tonalite/granodiorite type with less than 5% biotite. The latter type is locally mylonitic giving it almost a quartzite appearance and produces distinctive elongate hills which aid mapping methods. The foliated granite becomes gneissic in one locality. Rotated porphyroblasts suggest a sinistral sense of shear. Simple quartz-Kfeldspar pegmatites occurring as float masses or discrete dykes were recorded and there are some concordant mafic amphibolite or microgabbro lenses. Epidote-veined and sericitised altered varieties occur in Makutu-trend shear zones. The foliated granite may be in part derived from the Ntendele ?charnockitic to porphyroblastic granite.

5.2.4 Phyllonites

The phyllonites derived from granulite and granite rocks are characterised by chlorite, sericite, haematite and porphyroclastic streaked feldspars, boudinaged quartz and give rise to high relief features east and west of the Makutu Hills. In some localities they have streaked magnetite and specularite mica haematite. They are often strongly weathered and altered to haematite, goethite and clays in certain cuttings along the Isoka road north of the Main Makutu Range and at the N-S Mafingi-trend structure in the western margin of the basement outcrop. North of the Makutu Range in the Kamanga Reserve (north of Chanamo School) elongate N-S trending ridges show an assorted group of phyllites, thin quartzite bands and chlorite schist. Along the same trend north of the Muyalela River sericite, chlorite schist and phyllite together with thin amphibolite bands represent downgraded granite and ?charnockite.

5.2.5 Makutu Hills Group

The core lithologies of the Makuto Hills comprise sericite schists, sericite quartz phyllites, white fine grained orthoquartzite bands, recrystallised quartzite and a sequence of finely laminated haematitic metasediments cut by two cleavage structures locally. Platy quartz sericite phyllite with thin (up to 20 m) quartzites underlie the summit area of the Makutu Range in its central part whilst thick (more than 50 m) quartzites and sericite quartzite form strong topographic features on the western flanks separated by phyllites.

5.2.6 Superficial deposits

Much of the central area around Muyombe is covered by sandy to lateritic colluvium and this probably represents the remnants of a ?younger erosion surface formed in ?Tertiary times. Examples of eroded remnants include a blanket of Makutu quartzite boulders draped over Karroo-age arkoses near the Matenda River. the possibility of discriminating these erosion surfaces on the TM imagery has been cited above.

6.0 Further work

Considerable field checking is required in the northern and western Fungwe Forest area to ascertain the extent and limits of the Ubendian granites and ?charnockitic rocks together with their structural relationships to the foliated/sheared varieties in the south. The western flanks of the Makutu Hills require traversing to elucidate structural and lithostratigraphic relationships between Irumide and Ubendian tectonic events. New Landsat ETM imagery for the Muyombe area acquired in September, 1999 with 15 m resolution in panchromatic mode may assist with structural interpretation as well as providing clues on changes in land-use and hence improved access in the mountainous zone.

7.0 References

Fitches, W. R. 1971. Sedimentation and tectonics at the northeast end of the Irumide orogenic belt, N. Malawi and Zambia.. Geol. Rundschau, 59, 444-457.

Ring, U. 1993. Aspects of the kinematic history and mechanisms of superposition of the Proterozoic mobile belts of eastern Central Africa (northern Malawi and southern Tanzania). Precambrian Research, 62, 207-226. Amsterdam.