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REPORT ON FIELD GEOSCHOOL HELD IN TANZANIA, 24 AUGUST TO 25 SEPTEMBER 2009

by

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Introduction

The field Geoschool in Tanzania was run by Bob Thomas from 24 August to 25 September 2009. It was set up with the purpose of training six selected recent graduate geologists, newly-recruited to the Geological Survey of Tanzania (GST), in the skills of large-scale, regional field geological mapping. The participants had no prior experience of fieldwork or regional geological mapping. The schedule included two days start-up at the GST HQ in Dodoma in preparation for fieldwork, about three weeks in the field in SW Tanzania on a part of the complex, high-grade Palaeoproterozoic Ubendian Belt. A complete Arc-GIS project of the mapping area loaded onto a GETAC SIGMA mapping tablet computer, upon which all the field data was stored. After fieldwork, two days map compilation and reporting was completed at the GST, Dodoma.

Diary

21-22 August: Travel, Birmingham to Dar es Salaam via Dubai
23 August: Travel, Dar es Salaam to Dodoma by road
24-25 August: at Geological Survey (GST) in Dodoma
26 August: Travel, Dodoma to Chimala via Iringa
27 August: Visit regional and district offices in Mbeya to organize permits, find accommodation at church mission hospital in Chimala
28-29 August: Introduction to field mapping techniques in the area east of Chimala in high grade Ubendian paragneisses and intrusive granites
29 August: Rest day
30 August to 5 September: Continuation of basement mapping, with increasing independence of the 3 mapping pairs
6 September: Rest day
7 to 12 September: Continuation of basement mapping, with increasing independence of the 3 mapping pairs
13 September: Rest day
14 to 15 September: Field visit by Drs A. Mruma (CEO, GST) and W. McCourt (BGS)
16 September: Last day of fieldwork
17 to 18 September: Map compilation in Chimala
19 September: Scheduled to be travel from Chimala to Dodoma, but vehicle breakdown necessitated stay in Mbeya
20 September: Travel from Chimala to Dodoma via Iringa
21 September: Public holiday (Eid)
22 to 23 September: Map and report finalization at GST, Dodoma
24 September: Travel, to Dodoma Dar es Salaam by road, obtaining of permits for rock export from Ministry in Dar
25 to 26 September: In Dar-es-Salaam, early departure (05h00) on 26th.

Course introduction in Dodoma

The first morning I had a brief meeting with Dr Abdul Mruma (CEO of GST). He explained that the Chimala area was chosen for the Geoschool as it is composed of a complex high-grade Palaeoproterozoic (Ubendian) polyphase basement terrane, intruded by multi-phase igneous rocks, and overlain by a Neoproterozic clastic cover sequence (Bukoban). As such, the area is of comparable geological complexity to those to be mapped in the upcoming World Bank Tanzania project, in which the students are scheduled to play a major role.

Dr Mruma then (without any prior warning!) took me to the main lecture theatre where the entire company of the GST was assembled. After a brief introduction he invited me to address the staff on my mission. In my address I outlined the essentials of new geological mapping techniques and a general philosophy for large-scale regional geological surveys in Africa. I gave a visual demonstration of the Chimala ARC-GIS project in the SIGMA system, and outlined the recent advances made by BGS in the field of practical digital mapping techniques. Later, I was introduced to the six young, newly-qualified geologists (five from the University of Dar-es-Salaam, one from the university of Khartoum, Sudan) who were participating in the field school (*Hamisi Saidi; Shineni Ramadhan; Shemkee Mzee; Anton Kankila; Alex Masanja; Godson Kamihanda).*

During the first two days, processed airborne geophysical data (aeromagnetics and radiometrics) for the Chimala area was given to me by Mr. Jonas Mwano, which I georeferenced and entered into the GIS project. It is of quite low quality (large spaced flight-lines) and not very useful. Mr. Elly Brian Temu (Director, geological services) helped with our logistical needs and wrote the necessary permissions for working in the field areas. Before working in Tanzania, letters of authority from GST need to be presented to the relevant “RAS” (Regional Administrative Secretary) and “DAS” (District Administrative Secretary). I purchased two copies of the new (2004) 1: 2 000 000 scale geological and mineral map of Tanzania (by GST-BGRM-UDAR). During this period I met with Dr Pascal Semkiwa who is in charge of the preparation of tasks for the forthcoming World Bank projects with the GST.

We mainly spent the first two days preparing for the fieldwork. This involved sorting out the field equipment, maps etc. and explaining the protocols and procedures in regional geological mapping. In general, the field equipment available to the students from the GST stores was barely adequate, with no hand lenses available, only poor field hammers and no cameras. I bought a sledgehammer in Dodoma in order to be able to collect samples for possible geochronologcal analysis. We conducted some practical exercises in mapwork, including preliminary interpretations of the geological map to be studied. We covered all aspects of the map, including lithostratigraphy, lithology, structure and tectonics (including cross sections, 3D interpretation and the relationships between dip and topography), geomorphology, legend layout, geological history and background in East African geology. Sketch interpretations of the main elements of the 1: 125 000 Sheet Chimala were produced by each geologist, with a legend revised to modern standards and using modern nomenclature. A complete geological history of the area was elucidated.

Throughout this exercise I found all the geologists to be enthusiastic, hard-working and keen to learn. In many instances the discussions led to numerous digressions when I explained many related geological topics such as mineralogy, igneous and metamorphic rock classification, geochronology, plate tectonics etc.

Fieldwork

Two GST Land Cruisers in good repair with drivers were provided for fieldwork. It took a whole day to drive to Chimala via Iringa, where a 2 hour stop had to be made to present our letters of authority (as some of the fieldwork area falls in that district). In Chimala, we found excellent accommodation at the church mission hospital, including a large communal work area, for the 3 week stay. A cook was employed during weekdays to buy and make dinner. The whole of the first day in Chimala was spent visiting the RAS and DAS offices in Mbeya and Igawa and presenting our letters of authority.

Fieldwork proper commenced on 28 August. In order to maximise the time available, working days in the field were long (7 a.m to 6 p.m., six days a week). It was decided that the first few days would be spent on the eastern part of the Chimala Sheet, examining outcrops along the main Dar-es-Salaam to Zambia road (the "Tanzam Highway"). Due to the intensive interpretation on the sheet carried out in Dodoma, the students had a good working knowledge of the geology of the area and were able to point out many of the important geological and geomorphological features. I divided the students into three teams of two. The SIGMA mapping tablet computer was used to record all field data obtained by all the teams, so that a complete record of all sites documented would be available in digital format. While I could not train the students in the usage of SIGMA – they had no Arc background – they could at least see what was possible. During this traverse we encountered many of the supracrustal units of the high-grade Ubendian Group and a variety of intrusive units (porphyritic granite, hornblende tonalite, granitoid orthogneisses, alkali granite, mela- to leucogabbro). We found our recognized units to be at considerable variance with the published geological map. The Ubendian Group comprises a varied lithological (paragneiss) supracrustal assemblage (grey quartz-feldspar-biotite gneisses and migmatites; hornblende gneisses and amphibolites, garnet-sillimanite and Fe-quartzites, marbles, calc-silicate rocks, mafic-ultramafic rocks) which provided excellent teaching opportunities in rock and mineral identification, structure, metamorphic and igneous processes. Many discussions in the field were centred around these basic concepts. I found the students to be extremely keen to (re)learn the basic facts. In the central part of the traverse, the Ubendian rocks are unconformably overlain by the Neoproterozoic unmetamorphosed sedimentary rocks of the Bukoban Supergroup. The rocks are preserved in a gently S-plunging open syncline, so this afforded an excellent opportunity to cover sedimentary geology, although we did not concentrate much effort on these rocks. The description and classification of sedimentary rocks, sedimentary structures etc were, however, covered, along with deformation in the upper crustal brittle regime. The western part of the traverse provided an excellent training ground in superficial geology, including talus, alluvium and colluvial hillwash deposits. We even considered neotectonics and found evidence (at least locally) to discount

neotectonic movements along the fault as the southern margin of the Buhoro alluvial flats, as shown on the published geological map.

The complete main road traverse of some 65 km was completed within 4 days, with an average of just under one stop per kilometer. During the 4 days, the students had to be attuned to working quickly and efficiently at outcrops and to be able to get an understanding of the main points, without getting bogged down in detail, while at the same time trying to miss nothing of importance. The first days were naturally the slowest, but the pace gradually improved as confidence was gained in the mechanics of taking accurate dip and dip direction measurements quickly and mineral/rock identification. At almost every outcrop during the first week I gave illustrated (in my notebook) field talks on the background to the features being discussed, which are listed below. It was necessary, for example to draw and name the solid solution series of mineral groups such as the plagioclases, pyroxenes, amphiboles etc and explain a wide range of topics as diverse as enclave recognition and granitoid genesis, minimum-melt eutectics of the SiO_2 – K-feldspar binary system, strain partitioning in competent and incompetent materials and boudinage development etc. I found that whilst the students had a reasonable recognition of many of the terms used, they had little understanding of what they meant.

A field inspection by Drs Mruma and Bill McCourt (BGS) was carried out on 14 and 15 September. During the first day, the students each led 4 stops per group to illustrate the geology that had been mapped. The second day was spent doing a normal day's work, to illustrate the mapping technique of groups leapfrogging from outcrop to outcrop to maximize mapping efficiency, while allowing flexibility for group discussion at difficult and or complex/interesting outcrops by all participants and the course leader. During the second evening, I gave a demonstration of the SIGMA system and the ArcGIS project of the mapping area, showing examples of all the features such as the data inputs, photo downloads, sketch tool etc., with which Dr Mruma appeared duly impressed.

By the end of the fieldwork the students were all confident in their handling of the compass to measure accurately and reasonably quickly, dip and dip direction of planar surfaces, and linear structures such as mineral stretching lineations, fold axes, slickensides and dyke trends. They could generally identify correctly the main mineral species in coarse-grained rocks (but they only had one hand lens between them, apart from mine) and use mineralogical rock classification triangles to correctly name igneous and meta-igneous rocks. They could also name the metamorphic rocks encountered and make reasoned arguments for their possible protolith identity. The students learned sampling rationale and could collect fresh representative samples of the identified rock units. Field data sheets devised by the Geological Survey of Finland (GTK) were used for data entry and proved adequate for the task. The students got used to recording and describing what they saw at each outcrop, and enumerating such verbs as "large", "small" etc. Obviously they have not been turned into fully competent field mapping geologists of such complex geology as this in three weeks and it is vital that they be given their own mapping areas as soon as possible in order to hone the skills and information learned.

Field lectures

Ad Hoc field lectures were held on the following subjects, relevant to the particular outcrop under study:

- Crystallography and symmetry: Cubic, orthorhombic, monoclinic etc systems and petrographic implications;
- Mineral identification in the field: Quartz, feldspars, micas, pyroxenes, amphiboles, garnets, sillimanite, carbonates; Secondary minerals epidote, serpentines, chlorite, actinolite; Accessory minerals oxides, sulphides, titanite
- Mineralogy: Solid solution series of plagioclase; clino- and orthopyroxenes, olivines, chemistry of amphiboles, micas, the feldspar triangle and temperature (exsolution and perthites);
- Metamorphic geology: Facies concept, petrogenetic grids, indicator minerals and simple facies mineral parageneses, alumino-silicate polymorphs, P-T-t diagrams, prograde versus retrograde metamorphism, clockwise versus anticlockwise P-T-t loops, migmatites and their formation. Role of fluids, protolith interpretation;
- Igneous rock classification: IUGS-Le Maitre mineralogical triangles for granitoids and mafic-ultramafic rocks;
- Igneous petrology: Textural nomenclature, chemical compositions and physical characteristics of acid to ultramafic rocks, flow fabrics in igneous rocks, enclaves, granitoid genesis, minimum melts and simple eutectic phase diagrams, anatomy of volcanoes;
- Structural geology: Fold type, geometry and classification, phases of deformation, formation of S-fabrics (cleavage to schistosity to gneissosity and migmatite formation), fault geometry and cataclastic rocks, strain markers, strain partitioning and competency, kinematic indicators, mylonites, neotectonics, unconformities
- Sedimentary geology: Terminology, bedforms, younging, talus and colluvial deposits, recrystallisation;
- East African geology: Cratons, accretionary belts from Palaeoproterozoic to Mesozoic, African Plate tectonics through time, Tanzanian Precambrian evolution
- Lithostratigraphic nomenclature: Sedimentary and volcanic rocks, igneous rocks
- Landforms: break of slope, scarps, talus aprons;
- Scale in geology, fractal theory etc.

Sample collection

The students needed guidance in collecting representative, fresh samples and how to prepare samples for their collection, with as much weathered material removed in the field as possible. Considerations of grain size versus representivity were discussed. For BGS research purposes, I collected ten large samples of the various granitoids and orthogneisses of the area for possible U-Pb zircon dating in Norway. The Chimala region lies at a critical part of the SE Ubendian belt, and no dating has previously been carried out in this area. I am expecting a range of ages from the Palaeo- to the Neoproterozoic from the collected samples.

Field statistics (Chimala)

Days of fieldwork	14
Days of field inspection	2
Days in field office	3
Days obligatory local administration office visits	1
Vehicle breakdown returning to Dodoma	1
Rest days	3
Total days in Chimala *(excluding travel to and from Dodoma)*	**24**
Number of observation stations recorded (ca. 14 per day)	195
Number of samples collected	82
Approximate area mapped (km^2)	600

Map and legend compilation

During the evenings, the students were encouraged to compile the day's field data (lithological and structural) on their 1: 50 000 topographic field slip maps and a working legend of the units mapped was kept and added to as new mappable units were encountered. The global legend was fine-tuned and before completion started, the number of units of be shown on the map was agreed upon and numerical and colour codes assigned. However, the students found it impossible to keep the data on the field slips up to date, so two days had to be used after the last day of fieldwork for them to accomplish this task (17 and 18 September). This ate into the compilation time, already shortened due to the end of Ramadan and the Eid holidays during the last week of September. Compilation of the data at 1: 50 000 scale in such a complex geological terrane was always going to be difficult, and so it proved. I explained the basic principles attached to such an exercise, and the teams each made a valiant attempt, which I drew together on the evening of the 18 September. Although this exercise was somewhat rushed, a passable 1: 50 000 scale geological map resulted for an area of over 50% of the published 1; 125 000 geological sheet, Chimala, which was consistent with the observations and remote sensing data, and which is a marked improvement on the published geological map.

Return to Dodoma

Up until the day of return to Dodoma, the entire exercise had gone without a hitch. However, at the start of the journey, 40 km east of Chimala one of the vehicles developed a major fault and had to be towed back to the Toyota agent in Mbeya (80 km west of Chimala – i.e. away from Dodoma). Thus, a whole day was lost by the entire party waiting in Mbeya for the diagnosis of the fault. It transpired at 5 pm that the fault was so serious that it would take 2 weeks to fix. It was decided that the party would stay in Mbeya that night (19 Sept) and that the good vehicle would return to Dodoma the next day with 5 persons, with 4 students catching the public bus. The 5 (including RJT), left at 05h30 for Dodoma on 20 Sept. During the morning we learned that there was no public transport that day from Mbeya to Dodoma (due to Eid), so that the 4 students only got as

far back as Mgorogoro on 21 Sept, and completed their journey the following day on the Eid holiday (Monday 22 Sept).

Last days in Dodoma: report write-up

Before starting with the geological report of the mapping, a number of logistical and paperwork matters had to be attended to. A fair copy of the geological map compilation was made, and the colour scheme was changed to use more conventional colours for the rock-types recognised. The fair copy (falling on 3 x 1: 50 000 sheets) was then scanned as tif files at a commercial scanner in Dodoma (only A4 scanner at GST)

The geological report (Sheet explanation) was written in Dodoma on the last week of the course. Unfortunately, the advent of the Eid holiday was not taken into account during the scheduling of the Geoschool and Monday 21 September was lost. Added to this, the 4 students who returned by public transport from Mbeya over the previous two days were tired by this and were not as vigorous as usual. Despite this, good progress was made with the reporting. The students had no idea about how to write a "Sheet Explanation", so the whole process had to be taught from scratch. I did this by explaining the aims of such a report and we went through how it should be structured. Prof Mruma was especially concerned that the GST geologists were not very expert in reporting in general and the geological description of rock units in particular. Consequently, it was decided that, having been through the report structure, I would write all the background and introductory material myself, while each student would undertake to write the description of one of the main lithostratigraphic units recognised. I needed to gauge the level of competence that the students displayed at this process.

I had no idea how competent they would be at this process and it transpired that after half a day's work, only very short, rudimentary and linguistically poor descriptions resulted, which were not "editable" by me. Having had this benchmark set, on the final day of the course (Wednesday, 23 Sept) I then taught them the principles of the types of information required and asked them to re-write the descriptions. The second phase descriptions were much improved on the original attempts and were largely editable.

In the evening of the 23 Sept, we held a small social function at the New Dodoma Hotel with refreshments, where I presented the students with their certificates for having completed the course successfully.

Post-Geoschool work

Due to the unscheduled loss of Monday 21, the course was one day short. This resulted in the geological report not being completely finished. However, in many ways this is no bad thing as it gives the students the chance to do it for themselves, now that they have the skills to do so. The students were very keen that the report be completed, so it was agreed that they would complete the outstanding sections in the following few days. For my part, I agreed to edit their contributions and send them back, so that a final, edited report would result. I request a small amount of time be allocated to me or this purpose.

Conclusion

From my perspective, I think the Geoschool was an unmitigated success. It exceeded my expectations. The students were all very keen to learn and were prepared to work very hard, with very long hours in the field, followed by evening sessions. The many field lectures I gave were all by popular request and the students made every effort to absorb as much as possible of what I told them – they were constantly asking follow-up questions. They also requested extra teaching in Dodoma with topics written in a notebook, including practical petrography in the microscope laboratory, but regrettably there was no time for this. Before the course, the students all had a reasonable grasp of geological terminology, but did not know what most of the terms meant. This was put to rights. They had no idea how to conduct regional geological mapping in any type of geological setting, let alone a complex high-grade basement terrane such as the study area. While a four-week course cannot turn a newly-graduated geologist with no fieldwork experience into an expert mapper of high-grade basement rocks, I am sure that they now have the knowledge and self-confidence to undertake such work in the future.

Endpiece. R.J. Thomas delivers an impromptu field lecture on the outcrop (Ubendian gneisses, Chimala area, SW Tanzania).

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