TANZANIA GEOLOGICAL SOCIETY (TGS)

2021 ANNUAL CONFERENCE

BOOK OF ABSTRACTS

MOROGORO

26th to 30th October 2021

Front cover photos:

Top Left: *Kihansi spray toad - a small toad endemic to Udzungwa Mountains of Tanzania. Udzungwa Mountains are located in both Iringa and Morogoro regions;* ***Top Right:*** *A view of the Morogoro New Market, Chief Kingalu Market;* ***Bottom left:*** *Uluguru Mountain in Morogoro, favorable site for ruby, spinel and sapphire gemstones; and* ***Bottom right:*** *Traditional Luguru stool that is normally reserved for Luguru chiefs.*

Message to Participants of the TGS 2021 Conference

Dear participants,

On behalf of the TGS Executive Committee, it is our heartfelt pleasure to invite all geoscientists, engineers, academicians, young researchers, business delegates, and talented students from all geosciences perspectives to this year's TGS Conference. The TGS Conference Organizing Committee is particularly happy to be your host in the cool gentle winds of this beautiful and geologically interesting and exciting region. Welcome to Morogoro '*Mji Kasoro Bahari*', the land of opportunities, beauty and rich biodiversity of the Mikumi National Park, Selous Game Reserve, and Uluguru and Udzungwa mountains. This year's conference brings together a multidisciplinary group of brilliant geoscientists working in different sectors to interact and share different insights into the latest research, major milestones, experiences and new ideas related to the minerals, energy and water sectors of our country.

The TGS Conference Organizing Committee is also excited and looks forward to high quality and informative oral and poster presentations, and exhibitions of products and activities by geoscientist stakeholders. A special platform of renowned and experienced geoscientists from the government and private institutions will discuss some important aspect including Policy (framework) for Sustainable Extractive Industry Growth, Justifications for Establishment of Geoscientific Registration Board as a tool for Geoethics, and other discussions on issues of Tanzania's mineral, energy and water resources sectors.

This year's conference focuses on multiple issues one of which being gold mining activities especially by artisanal and small scale miners. For many years gold has been regarded prospective within the greenstone belts of Tanzania, however recent trends of gold rush by artisanal miners suggest otherwise. Huge potential unlocks from high grade metamorphic belts such as that of Morogoro region. With more gold mining sites emerging, the challenge remained on how to finance prospecting and mining activities at small and medium scale levels. Moreover, on mineral markets, Tanzania has seen a very good mineral business performance related to Mineral and Gem Houses under the Mining Commission of Tanzania. Yet, the question is

whether the performance of the Houses is adequate or not and whether the technical capability at the Houses is sufficient for development of the mineral sector.

It is anticipated that the conference will offer an important opportunity to further a discussion on different aspects of critical resources, such as graphite that are available in Morogoro and the rest of the Mozambique Belt of Tanzania. Does the pace by policy makers in regulating the market for the minerals match the pace and dynamics of the international market demands on the minerals? The same uncertainty can be viewed for REE minerals which have a massive contribution to the ongoing advancement in military capabilities and technological industries of the world. How best the REE mineral resources such as that of Wigu Hill can be best exploited? It is still a matter of discussion among geoscientist stakeholders.

Contribution of geoscientists to energy and water resources sectors, which make integral components for human survival and development, will not be left out during the conference. Backgrounds and highlights of these issues for Tanzania are summarised here. About 80% of energy consumption in Tanzania is from biomass most of which release massive content of carbon dioxide to the atmosphere. Thus exuberating concerns about Climate Change. With the current world policy of reducing global emission of greenhouse gases, Tanzania needs to have environmentally friendly energy sources. Energy mix is undoubtedly an important option to a stable power supply and consequently sustainable industrial development. The Julius Nyerere Hydroelectric Power dam which is under construction in the Rufiji Basin is projected to have a maximum capacity of 2,115 MW that will be enough power for the nation's consumption. However, presences of geothermal resources, favourable sites for extracting wind energy and favourable geographic location that allow maximum tapping of solar energy give room for Tanzania to have a well organized energy mix for security of a nation.

An important point for deliberation would be on the fact that exploration efforts for hydrocarbons in Tanzania began in the 1950s, but still there is no commercial oil discovery that has been made to date. This occurs at a time when potential indicators and key petroleum system elements are present and

well known in the sedimentary basins of Tanzania. Oil seeps which are direct indicators of a working petroleum system are among these indicators. One should also be mindful that more than 60% of the world's oil reserves have been discovered in the salt basins. The Mandawa Basin of southern Tanzania is among the salt basins of the world, but yet none of oil accumulations has been discovered in the basin. The question is where do we go wrong? Some have argued that complex salt tectonics is the main reason for delayed discovery in Mandawa. Although, the same does not explain for no oil discovery in other basins of Tanzania.

Tanzania has multiple water sources including rivers, lakes and underground water systems. Access to clean and safe water remained below 50% of the population. Effort by the Tanzania Government cannot be understated; many water projects are currently ongoing. To the geoscientific community the issues would be what can geoscientists offer? Does investment in underground water exploration and exploitation match the output? This will be an important point of discussion during this conference. Last but not least in importance, it is clear that the geoscientific ethical codes have failed to pace with the advancement of geosciences and related careers in Tanzania. This led to once again TGS Executive Committee to host a Stakeholders meeting on Tanzania Geoscientific Registration Board to collect different opinions on establishment of the board from stakeholders and TGS members.

The Tanzania Geological Society is grateful to all TGS members and all those who volunteered in one way or another to make this conference a success. Special thanks to our sponsors and partners for their generosity and enthusiastic support: Tanzania Petroleum Development Corporation, Bank of Tanzania, National Microfinace Bank, Barrick Gold Corporation, University of Dar es Salaam, National Environmental Management Council, Sunshine Mining Limited, Geological Survey of Tanzania, The Mining Commission of Tanzania and TANESCO. Conference Organizing Committee is hugely indebted for their continued support.

Conference Organizing Committee

Tanzania Geological Society (TGS)

Conference Organising Committee

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Our Gold Sponsor

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Geita Gold Mine, one of the AngloGold Ashanti's flagship mines, is located in north-western Tanzania, in the Lake Victoria goldfields of Mwanza region, about 120 km from Mwanza and 4 km west of the town of Geita. It has been in operation as a large-scale mine since the 1930s. The Geita gold deposit is mined as a multiple open-pit and underground operation since 2016 and will continue to operate as such until the entire economic open-pit Mineral Resource is exhausted. The mine is currently serviced by a carbon-in-leach processing plant with an annual capacity of 5.1Mt.

As at 31 December 2018, the Mineral Resource is 6.26 million ounces. Approximately 4,130m of development was completed for the Star & Comet and Nyankanga underground sections, to access new areas for stope mining and for further exploration, in 2018. Open-pit mining at Nyankanga and Geita Hill continued with Geita Hill reaching the end of its economic life and Nyankanga scheduled to be completed in the first half of 2019. Surface exploration continued at Selous, a satellite pit 2.4km from Star & Comet, expected to supplement the underground operation in the near term.

Other notable projects at Geita were completion of the 40MW power plant and the purchase of underground mining plant and equipment. The power plant was commissioned in August and is currently in full operation, providing reliable, low-cost power to the mining operations. The purchase of the underground mining plant and equipment is in line with the strategy to transition to owner mining at Star & Comet, planned for the first half of 2019, with the full change over for the rest of the mine's sections expected to follow in coming years.

Our Silver Sponsor

Tanzania Petroleum Development Corporation

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Tanzania Petroleum Development Corporation (TPDC) is the National Oil Company of Tanzania through which the Ministry of Energy implements its petroleum exploration and development policies. TPDC has a manpower strength of about 400 and is organized into six (6) directorates and four (4) units, namely: Directorate of Exploration Development and Production, Directorate of Oil and Gas Business, Directorate of Planning and Investment, Directorate of Finance and Administration, Directorate of Legal Services, Directorate of Internal Audit, ICT and Statistics Unit, Procurement Management Unit, Public Relations and Communication Unit and Risk Management Unit. TPDC was established through the Government Notice No.140 of 30th of May 1969 under the Public Corporations Act No.17 of 1969. The Corporation began operations in 1973. TPDC is a wholly owned Government parastatal, with all its shares held by the Treasurer Registrar.

TPDC Vision is to become a leading integrated National Oil and Gas Company competing nationally, regionally and globally in an environmentally responsible manner to the benefit of all stakeholders; whereas Mission is to participate and engage in the exploration, development, production and distribution of oil and gas and related services; facilitate a fair trading environment; safeguard the national supply of petroleum products; at the same time developing quality and safety standards to protect people, property and the environment.

Our Silver Sponsor

Bank of Tanzania (BOT)

https://www.bot.go.tz

The Bank of Tanzania is the Central Bank of the United Republic of Tanzania established by the Bank of Tanzania Act of 1965, it became operational on 14th of June 1966. Various amendments to the Bank of Tanzania Act have been made leading to the Bank of Tanzania Act of 1978 and the Bank of Tanzania Act of 1995. Presently, the Bank of Tanzania operates under the Bank of Tanzania Act, 2006. The Bank of Tanzania Mission and Vision is to "Maintain price stability and integrity of the financial system for inclusive economic growth" and " To be a Central Bank that effectively fosters macro-economic stability and modernized financial system in sustenance of country's middle-income status and beyond " respectively.

In Memoriam

Prof. Hudson Hamisi Nkotagu

(1956 – 2021)

As we are convening for this year's annual conference, TGS is commemorating Professor Hudson H. Nkotagu who has been featured in this Book of Abstracts. A token of appreciation is extended for his endeavours to hydrogeology and for being one of the first and senior Tanzanian hydrogeologists. Prof. Hudson Hamisi Nkotagu dedicated much of his time in teaching, research and development of earth sciences in the country and beyond. He made an impact that will live for generations to come. May his soul rest in eternal peace and his family find solace in his memory.

Editorial Team

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TGS 2021 Conference Abstract Titles

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Conference Programme

DAY 1 & 2 (26-10-2021 & 27-10-2021)

EXCURSION

Tuesday 26.10.2021	
Time	**Stop/ Activity**
06:00 - 06:25	Meeting at the Department of Geosciences UDSM before start of the excursion
06:30	Departing from the Department of Geosciences to Rufiji
06:30 - 11:30	Driving toward Rufiji via Kisarawe
11:30 - 15:00	Touring within project premises, at Rufiji, JNHPP
15:00 - 20:00	Departing Rufiji JNHPP, driving to Mkuranga
20:00 - 06:30	Spending night at APC Hotel & Conference Centre
Wednesday 27.10.2021	
Time	**Place/ Activity**
06:30 - 11:30	Departing from Mkuranga to Mikese via Dar es Salaam
11:30 - 12:30	Mikese, Jensen Quarry
12:30 - 13:15	Driving to Morogoro
13:15 - 14:15	Lunch Break
14:15 - 15:15	Mindu quarry
15:30 - 17:30	Sokoine University, Solomon Mahlangu Campus, Mazimbu, Morogoro

DAY 3 (28-10-2021) ***OPENING***

Time	**Activity**	
07:30 - 09:00	Arrival, Registration & Breakfast	
09:00 - 09:15	TGS General Secretary: Welcoming remarks	
09:15 - 09:40	Greetings from the Gold sponsor	
09:40 - 10:15	TGS President: Speech, and to welcome Guest of Honour	
10:15 - 11:15	Guest of Honour	
11:15 - 11:20	Photo session	
11:20 - 11:30	HEALTH BREAK	
Time	**Presenter**	**Title**
11:30 - 11:50	Nelson Boniface	New tectonic model and division of the Ubendian-Usagaran Belt, Tanzania: a review and insitu dating of eclogites
11:50 - 12:10	Athanas Macheyeki	Conventional versus non-conventional mineral exploration techniques
12:10 - 12:30	Gloria J. Joseph	The tax regime and mineral exploration industry of Tanzania
12:30 - 12:50	Selina A. Deng'hen	Commercial banks contribution to small scale miners access funds
12:50 - 13:10	Kenneth Nzowa	Financial support services to artisanal and small-scale mining projects in Tanzania: a critical evaluation
13:10 - 13:30	Julius Sarota	Mining Projects Financing - General Perspective
13:30 - 14:30	LUNCH BREAK	
PANEL DISCUSSION ON MINERAL SECTOR: Financing Mining Projects, Effective Mineral Marketing Strategies & Development in Small Scale Mining of Tanzania		
14:30 - 16:00 Convenor: **Ms. Bertha Luzabiko**	Federation of Miners Association of Tanzania (FEMATA)	
	Mining Commission of Tanzania	
	National Microfinance Bank (NMB)	
	Bank of Tanzania (BOT)	
16:00 - 16:10	HEALTH BREAK	
PRESENTATIONS by Tanzania Mining Commission		
16:10 - 17:40 Convenor: **Dr. J. Kabete**	RMO Singida	
	RMO Geita	
	RMO Kilimanjaro	
	RMO Tabora	
17:40 - 17:45	**End of Session & Announcements**	
18:00 - onwards	**Cocktail Party**	

DAY 4 (29-10-2021)

Time	Presenter	Title
08:00 - 09:00	Arrival, Registration & Fixing Posters	
09:00 - 09:20	Isaac Marobhe	Satellite gravity anomalies of Coastal Tanzania: defining the sedimentary basins.
09:20 - 09:45	Karim Mtili	The origin of high helium concentrations in the gas fields of South-western Tanzania.
09:45 - 10:10	Clarah Kimani	He, Ne, Ar and CO_2 systematics of the Rungwe Volcanic Province, Tanzania: Implications for fluid source and dynamics.
10:10 - 10:30	Remigius Gama	The anomalously-propagating South Kenya Rift in the context of the North Tanzanian Divergence Zone, East Africa.
10:30 - 10:50	HEALTH BREAK	
10:50 - 11:10	Erick Kivera	Overview of Petroleum sub-sector in Tanzania, TPDC projects
11:10 - 11:30	Sindi Maduhu	Improved Depth estimates of subsurface sources structures using 2D/3D modeling of potential field data: implications for Hydrocarbon exploration.
PANEL DISCUSSION ON ENERGY **Oil and Gas potential in Tanzania & Energy mix for sustainable development**		
11:30 - 13:00 Convenor: **Dr. M. Kagya**	Tanzania Petroleum Development Corporation (TPDC)	
	Tanzania Geothermal Development Corporation (TGDC)	
	SONGAS	
	TANESCO	
13:00 - 14:00	LUNCH BREAK	
14:00 - 14:20	Paschal Njiku	Tanzania upstream development and liquefied natural gas project.
14:20 - 14:40	Venance Mboya	Sedimentology and stratigraphic of Mesozoic succession from Tanga and Ruvu Sub Basins.
14:40 - 15:00	Emily Kiswaka	Palaeodepositional conditions of Permian organic-carbon-rich deposits of the Helgeland Basin, offshore Mid Norway, based on elemental proxies and core logging.
15:00 - 15:20	HEALTH BREAK	
15:20 - 15:40	Epiphania Mutabazi	2D and 3D lithosphere model of the southwest Tanzania Rift System, from geological and gravity data.
15:40 - 16:00	Sara Emanuel	Paleoceanographic evolution in the South China Sea from the Upper Pliocene To Pleistocene on the basis of calcareous nannofossil assemblages.
16:00 - 16:20	Nyora Kobare	Geochemical investigation on the fluid origin, subsurface processes and recharge with its implications to the Tangkuban Perahu geothermal conceptual model.
16:20 - 16:40	Athanas Macheyeki	The Chenene ground fractures relay ramps and hot springs in the Bahi Basin bordering faults and implication for rifting manifestation and geo-hazards in the Dodoma area, Tanzania.
PANEL DISCUSSION ON WATER RESOURCES: **Improved water supply and sanitation for social economic development in Tanzania**		
16:40 - 18:10 Convenor: **Prof. E. Mbede**	Rural Water Supply and Sanitation Agency (RUWASA)	
	Rwegarulila Water Resources Institute, Dar es Salaam	
	University of Dar es Salaam	
18:10 - 18:15	**Announcements & End of day 4**	

DAY 5 (30-10-2021)

Time	Presenter	Title
08:00 - 08:30	Arrival	
08:30 - 08:50	Kasanzu Charles	Isotopic and geochemical constraints on the protolith, redox state and paleo-tectonic setting of the Malagarasi Supergroup of North-Western Tanzania: northwards flow of the Proto-Congo river in the Rodinia Realm
08:50 - 09:10	Joas Kabete	The Geologic-tectonic setting of the Tectonic Front and SEAO of Tanzania: a motivation to exploration companies
09:10 - 09:30	Gerald Chuwa	Geochemistry and petrography of intrusive sills from the Karagwe Ankolean Belt (KAB), Northwestern Tanzania: constraints on origin, tectonic environment and petrogenesis
09:30 - 11:00	**STAKEHOLDERS MEETING on Proposal for Tanzania Geoscientific Registration Board (TGRB) Conveners: Mr. Denis Mahimbo & Dr. Elisante Mshiu**	
CLOSING, TGS 2021 ANNUAL CONFERENCE		
11:00 - 11:15	TGS Vice President, TGS: Welcoming remarks	
11:15 - 11:45	TGS President: Speech, and to welcome Guest of Honour	
11:45 - 12:45	Guest of Honour	
12:45 - 12:55	Photo session	
13:00 - 14:00	LUNCH BREAK	
TGS ANNUAL MEETING		
Time	**Activity**	**Responsible**
14:00 - 14:20	Opening	TGS President
14:20 - 15:50	Reporting on TGS 2020/2021 Activities & Financial Report (Auditors report)	TGS General Secretary & Treasurer
15:50 - 16:20	TGS Office in Dodoma/ Permanent address	Deputy General Secretary
16:20 - 16:40	TGS Training Institute Plans	TGS Editor
16:40 - 17:00	TGS Journal Plans	
17: 00 - 17:10	Closing	TGS Vice President
18:00 - onwards	**WORKSHOP DINNER**	

POSTER PRESENTATIONS

Presenter	**Poster title**
Venance Mboya	Tectonic evolution of Seagap Fault Zone: it's implication to sediment distribution in mafia deep basin
Adam Sajilo & Victoria Godfrey	TPDC laboratory services
Mariam Kiaze	Petrophysical analysis of the potential reservoir rocks intersected by Papa-1 well of exploration Block 3, offshore Tanzania
Emmanuel Kazimoto	Mineralogy and lead isotopes composition of polymetallic vein deposits of the Mpanda Mineral Field in Katavi Tanzania
Erick Kivera	Analysis of the Neogene sediments from Eyasi- Wembere Basins, Northern Eastern Tanzania
Neema Maganza	Hydrocarbon source rock potentiality in ruvu basin: a case study for Middle Jurassic -Bajocian Shale
Sindi Maduhu	Optimization of 2D seismic survey design in Eyasi-Wembere Basin using 2D/3D modeling of potential field data
Stephen Magohe	Fossil plant leaves from the onshore Tanga Basin, Tanzania: insights into Gondwana phytogeographic Province
Tryphone Ndubusa	The impacts of production and reservoir properties on the ultimate recovery and production behaviors of gas condensate reservoirs under the bottom water drive mechanism

GEOCHEMICAL INVESTIGATION ON THE FLUID ORIGIN, SUBSURFACE PROCESSES AND RECHARGE WITH ITS IMPLICATIONS TO THE TANGKUBAN PERAHU GEOTHERMAL CONCEPTUAL MODEL

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Tangkuban-Perahu and nearby areas are the most important geothermal prospect in West Java, Indonesia that is believed to be volcano-hosted geothermal systems. Recharge and geothermal fluid evolution have not yet been fully understood. This is due to complexities of fluid origin, subsurface processes and variations of series of manifestations around the prospect. This study describes the origin, processes and evolution of geothermal fluids in connection to recharge and conceptual model of the Tangkuban-Perahu Geothermal Systems (TPGS). This study involved sampling and analysis of 9 geothermal water samples, 4 rainwater and 6 gases collected in fumaroles and other manifestations of the Tangkuban-Perahu. Deuterium (δ^2H) and oxygen isotope ($\delta^{18}O$) were used together with conservative elements such as B, Cl and rare alkali metals analyses to determine the origin of fluids and describe subsurface processes as the fluid migrates to the surface as discharge. The isotopic values ($\delta^{18}O$ and δ^2H) of thermal and rainwater indicate deep-circulating meteoric origin, at an infiltration altitude ranging between 753-850masl in low terrain. Meanwhile the high standing terrain indicates the recharge zone to be around the wall of the Sunda caldera and mountain slopes at 1378 masl. Chondrite normalized patterns exhibit an overall negative slope that suggest enrichment of Lower Rare Earth Elements (LREEs). The non-atmospheric gases origin was diagnosed by the lower N_2/Ar (≤ 38) and is characterized by meteoric source origin. The idea that the geothermal water mixes with shallow groundwater is substantiated using different mixing models and geoindicator analysis. The positive $\delta^{18}O$ shifts

from Kancah (KC), Batu Gede (BG) and Domas crater (KwD) thermal waters relative to the local meteoric lines are primarily due to interaction with host rocks or magmatic influx. In these geothermal systems, fluids are heated by the heat source and geothermal gradient, followed by partial discharge as thermal springs and fumaroles to the surface along faults and fractures that act as hydrothermal conduits. By integrating with the surface geology and faults trends the geothermal conceptual model was developed for the geothermal fluids flow system in the region.

PETROPHYSICAL ANALYSIS OF THE POTENTIAL RESERVOIR ROCKS INTERSECTED BY PAPA-1 WELL OF EXPLORATION BLOCK 3, OFFSHORE TANZANIA

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This work reports petrophysical analysis of the late Cretaceous (Campanian) deep water turbidite sandstone reservoir of Papa 1 well at exploration Block 3, offshore southern Tanzania. The main objective of the study was to assess the hydrocarbon reservoir potential of sedimentary units encountered in Papa-1 well using well logs data. The data sets that were available to the study included the gamma ray, density, neutron, resistivity and sonic logs. The organization, processing and evaluation of the well logs data were done using the Tech-log software in order to establish lithology, porosity, permeability, water saturation (Sw) and hydrocarbon saturation (Sh) of the penetrated formation.

The Papa-1 well was evaluated and one sandstone reservoir zone, which is a gas bearing, was encountered at a depth interval of 4657.7 - 5049.6 m. The reservoir has an average porosity of 17.5 v/v and average permeability of 4.53 mD indicates good porosity but poor permeability, as a result of high shale volume (0.184v/v). The net thickness of this reservoir is 391.9 m and has a net gross ratio of 0.87. The water saturation (Sw) of the reservoir is 58.5% and its hydrocarbon saturation (Sh) is 41.5%.

Generally, the reservoir encountered in Papa-1 well is petroliferous and this well could serve as a control well for future petroleum exploration activities in the study area with channel fills as targets. It is recommended that more wells need to be drilled in and around block 3 in order to confirm the presence of oil and gas and more information about distribution of reservoirs in the deep waters of southern coastal Tanzania should be collected.

GEOCHEMISTRY AND PETROGRAPHY OF INTRUSIVE SILLS FROM THE KARAGWE ANKOLEAN BELT (KAB), NORTHWESTERN TANZANIA: CONSTRAINTS ON ORIGIN, TECTONIC ENVIRONMENT AND PETROGENESIS

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Whole-rock geochemistry was applied to provide insights into the origin, tectonic settings of emplacement and petrogenetic processes of intrusive sills in the eastern part of the Karagwe-Ankolean Belt (KAB). These insights are crucial in understanding the complex tectonic and magmatic evolution of the belt. The sills intruded low-grade interbedded metamorphosed siliciclastic and pelitic rocks of the Mesoproterozoic KAB. Past workers have classified these rocks into micro-gabbro, dolerite and diorite based on their mineralogical composition, textures and field relationships. Thirteen representative samples collected for this study included 8 micro-gabbro samples from Ngara and 5 dolerite samples from the Biharamulo districts within the KAB of northwestern Tanzania.

The samples are classified in the gabbro to diorites field equivalent to andesitic basalts (SiO_2 = 52-56 wt. %) in the total alkali-silica plot (TAS) and are evolved with Mg# 41 – 67. They classify as continental alkaline basalts in the binary plot of trace elements ratios Th/Yb against Ta/Yb. The rocks contain Cr = 70 – 990 ppm; Co = 26 – 48 ppm; Ni = 10 – 60 ppm; Sr = 84 – 153 ppm; Zr = 59 – 105 ppm and Ba = 53 – 254 ppm. Samples trace element ratios La/Nb = 2.8 – 5.15 and La/Ta = 45 - 58 are akin to crustal or mantle lithosphere contamination.

Trace elements Nb, Ta, Sr and Ti depict troughs in the primitive mantle normalized spider plot, typical feature of arc lavas or fractional crystallization processes. In the chondrite normalized REE spider diagram, the samples show elevated LREE compared to MREE and HREE (La/Yb_{CN} = 2.3 – 5.3). A negative Eu* anomaly (Eu*= 0.74 – 0.94) highlights mild

plagioclase fractionation from the original melt. Trace element ratios Ta/Yb - Th/Yb, Zr - Zr/Y and plot of Zr against Ti suggest these rocks are of continental volcanic arc basalts origin, whereas the ratios of Zr/Nb and Zr/Y constrains their source similar to that of normal Mid Oceanic Ridge Basalts (NMORB). In addition, the gabbroic to dioritic sills in the Ngara and Biharamulo districts have elevated LREE and HFSE contents compared with mafic sills from the Kabanga Musongati intrusive samples.

As most of previous works regard the rocks to relate to metalliferous mafic-ultramafic intrusives of the Kabanga-Musongati alignment, geochemical features obtained in this study calls for further studies to ascertain this hypothesis. Future work on isotope geochemistry of the rocks is envisaged to provide more answers on the origin of rocks and their tectonic setting of emplacement.

ISOTOPIC AND GEOCHEMICAL CONSTRAINTS ON THE PROTOLITH, REDOX STATE AND PALEO-TECTONIC SETTING OF THE MALAGARASI SUPERGROUP OF NORTH-WESTERN TANZANIA: NORTHWARDS FLOW OF THE PROTO-CONGO RIVER IN THE RODINIA REALM

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We report detrital zircon U-Pb ages, radiogenic Sm-Nd isotopic compositions, major and trace element compositions of the intra-plate extensional rhomb-shaped Neoproterozoic Malagarasi Supergroup of north-western Tanzania in order to elucidate the paleo-tectonic setting, source rocks chemistry and paleo-oxygenation in the basin. Assuming that provenance trace element proxy ratios, including the rare earth elements (REE) contents, behave as closed systems during sedimentation and diagenesis, we suggest that the detritus for the basin originated from more felsic rocks than those for upper crustal composites (i.e. Post-Archean Australian Shale; PAAS, Proterozoic Shale; PS). This observation is also supported by enriched chondrite-normalized light REE (La/Sm_{CN} = 2.36-7.84; mean = 3.85), overall negative Eu anomalies (Eu/Eu^{*} = 0.56-0.93; mean = 0.69) and flat heavy REE patterns (Gd/Yb_{CN} = 1.01-2.04; mean = 1.47). Paleo-weathering proxies using the Chemical Index of Alteration (CIA ~59-78%) protocol indicate an overall moderate weathering intensity in the basin. V/Cr ratios (mean = 1.18; range = 0.48-1.69) coupled with intra-sample Ce anomalies reveal an overall oxidizing state during deposition. Mantle extraction ages (TDM = 1594-2394 Ma) suggest a diverse mixing of protolith terranes including Archean (Tanzania craton), Eburnian (Ubendian Belt) and possibly the nearby Mesoproterozoic Kibaran Belt. Radiogenic laser ablation detrital zircon U-Pb ages of between 1826 to 2656 Ma may preclude contribution from the Kibaran. Given that Nd systematics in

sedimentary rocks provide mixing ages of different hinterland source rocks (1594 - 2394 Ma; in our study), we suggest relatively juvenile sources such as the local post-orogenic effusive bodies farther south of the basin in the realm of Rodinia Supercontinent. Thus a northerly flow direction of the proto/paleo river system in the region is inferred.

THE CHENENE GROUND FRACTURES, RELAY RAMPS AND HOT SPRINGS IN THE BAHI BASIN BORDERING FAULTS AND IMPLICATION FOR RIFTING MANIFESTATION AND GEO-HAZARDS IN THE DODOMA AREA, TANZANIA

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Active faulting is theoretically an obvious fact within the East African Rift System environment. Yet in reality, it might not be easy to tell exactly what factors are indicative of active faulting and active rifting. In this work structural features such as ground fractures and relay ramps attitudes are presented as structural indicators of active faulting and rifting. Furthermore, hot springs are reported here as additional features for active rifting within and near the Bahi Basin. Both ground fractures and hot spring patterns indicate that the current extensional direction of the rift within the Dodoma area (including the Bahi basin) is almost E-W and that the rifting process poses some threats to big infrastructures such as tall buildings, dams, tunnels and bridges.

CONVENTIONAL VERSUS NON-CONVENTIONAL MINERAL EXPLORATION TECHNIQUES

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Conventional mineral exploration techniques span over centuries. Their power to depict economic mineral deposits over time cannot be undermined for they have helped mineral explorers and miners to shape our world. Some of the commonly known conventional techniques include gold nugget picking, identification of anomalous values within a geochemical data set without considering geochemical outliers, computation of geochemical threshold using 2 x standard deviation plus mean value etc.

Recently, the pace of mineral deposit discoveries using conventional techniques has been increasingly frustrated by the diminishing or depletion trend of economic mineral deposits owing to the fast growing population against the geometric need of the minerals for either industrial uses, for armaments or for ornaments. In recent decades, scientists have embarrassed the use multi-mineral exploration techniques in mineral exploration, most of which are non-conventional; they include Remote sensing, Lithogeochemistry, Fractal models, Concentration gradient modeling, Mineral prospectivity mapping, biogeochemistry, among many non-conventional mineral exploration techniques. Some of these techniques are useful at regional scale and some at prospect scales and some at different scales. This article presents both lithogeochemical models, concentration gradient and fractal models for demonstration on how to quickly and reliably discover mineral deposits at different stages of mineral exploration endeavors.

SATELLITE GRAVITY ANOMALIES OF COASTAL TANZANIA; DEFINING THE SEDIMENTARY BASINS

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This study reports on the work that has been conducted to process and interpret satellite gravity data of coastal Tanzania. The study covers an area located 37.5°E to 42.0°E and 4.0°S to 11.5°S. The gravity data together with DEM/ Bathometry data were downloaded from global satellite data. The Free air gravity data were downloaded and processed to get Bouguer anomalies of coastal Tanzania. The Bouguer anomaly map was then filtered using different wavelengths in order to separate noise, local, and regional anomalies due to Moho discontinuity. Anomalies with wavelength less 14 km were found to represent noise anomalies with amplitudes in the order of 3 to 6 mGals, Anomalies with wavelength between 14 km to 150 km were found to define anomalies due to sedimentary basins with amplitudes ranging from -20 to +90 mgals, whereas anomalies with wavelengths greater than 150 km were found to represent deep seated anomalies with high amplitudes in the order of -90 to 182 mgals. Deep seated anomalies increase from west to east reflecting presence of oceanic crust and shallow Moho discontinuity in the east and thick continental crust towards the west. Several sedimentary basins in the north such as Tanga basin, Mafia basin have been revealed occurring as grabens trending NNE/SSW, others in the south trend NNW/SSE, N/S and E/W. The anomalies have also been compared with successful gas bearing borehole locations. The satellite data may be used successfully to define the sedimentary basins in coastal areas.

THE IMPACTS OF PRODUCTION AND RESERVOIR PROPERTIES ON THE ULTIMATE RECOVERY AND PRODUCTION BEHAVIOURS OF GAS CONDENSATE RESERVOIRS UNDER THE BOTTOM WATER DRIVE MECHANISM

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This study presents a comprehensive review of the effects of production schemes and reservoir properties on the ultimate recovery and production trends of gas condensate reservoirs under the bottom water drive mechanism. The study aims to provide reservoir geologists and engineers with a strategy for optimizing the development, prolong field life, and maximize recovery of bottom water-driven gas condensate reservoirs. The approach focused on the review of the simulated results of various constructed radial numerical models from different producing gas condensate reservoirs in various fields in the world. Technical papers and journals concerning hydrocarbon recovery and production were also reviewed in which all factors that have potential impact on gas and oil ultimate recoveries such as gas production rate, completion length, aquifer size, horizontal permeability, and permeability anisotropy were thoroughly studied.

Technological efforts to outwit challenges facing bottom water-driven gas reservoirs such as water coning were reviewed as well. Results showed that a low gas production rate is more preferred to prolong field production life, minimize water production and water breakthrough time in gas condensate reservoirs. The effect of aquifer size in gas recovery is not very much pronounced though the gas recovery increases with an increase in aquifer size up to aquifer size, (M)=10, and then starts to decrease. It is also observed that the permeability anisotropy has a negligible influence on both gas recovery and field production life but affect the water breakthrough time and total water production which can be controlled by the Downhole Gas-Water

Separator and Downhole Water Sink technologies, and for maximum gas recovery from the reservoir, the gas zone has to be totally perforated.

NEW TECTONIC MODEL AND DIVISION OF THE UBENDIAN-USAGARAN BELT, TANZANIA: A REVIEW AND INSITU DATING OF ECLOGITES

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Records of high-pressure/low-temperature (HP-LT) metamorphic interfaces are not common in Precambrian orogens. It should be noted that the association of HP-LT metamorphic interfaces and strongly deformed ocean plate stratigraphy that form accretionary prisms between trenches and magmatic arcs are recognized as hallmark signatures of modern plate tectonics. In East Africa (Tanzania), the Paleoproterozoic Ubendian-Usagaran Belt records a HP-LT metamorphic interface that we consider as a centerpiece in reviewing the description of tectonic units of the Ubendian-Usagaran Belt and defining a new tectonic model. Our new U-Pb zircon age and the interpretations from existing data reveal an age between 1920 and 1890 Ma from the kyanite bearing eclogites. This establishment adds to the information of already known HP-LT metamorphic events at 2000 Ma, 1890–1860 Ma, and 590–520 Ma from the Ubendian-Usagaran Belt. Arc–back-arc signatures from eclogites imply that their mafic protoliths were probably eroded from arc basalt above a subduction zone and were channeled into a subduction zone as mélanges and got metamorphosed. The Ubendian-Usagaran events also record rifting, arc and back-arc magmatism, collisional, and hydrothermal events that preceded or followed HP-LT tectonic events. Our new tectonic subdivision of the Ubendian Belt is described as: (1) the western Ubendian Corridor, mainly composed of two Proterozoic suture zones (subduction at 2000, 1920–1890, Ma and 590–500 Ma) in the Ufipa and Nyika Terranes; (2) the central Ubendian Corridor, predominated by metamorphosed mafic-ultramafic rocks in the Ubende, Mbozi, and Upangwa

Terranes that include the 1890–1860 Ma eclogites with mid-ocean ridge basalt affinity in the Ubende Terrane; and (3) the eastern Ubendian Corridor (the Katuma and Lupa Terranes), characterized by reworked Archean crust.

FOSSIL PLANT LEAVES FROM THE ONSHORE TANGA BASIN, TANZANIA: INSIGHTS INTO GONDWANA PHYTOGEOGRAPHIC PROVINCE

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We present the Late Permian to Late Triassic fossil plant leaves recovered from the Kakindu outcrop of the Tanga Basin. These include Glossopteridales (*Hirsutum dutoitides*, *Sphenobaiera eccaensis*), Ginkgoales, Peltaspermales (*Lepidopteris madagascariensis*) and Voltziales/ Coniferales (*Ginkgoites dutoitii*). The Glossopteridales genera *Hirsutum dutoitides* and *Sphenobaiera eccaensis* were speculated not likely to be present in the Kakindu Beds during the earlier studies, and thus the only data available were used to infer depositional ages of the Kakindu Beds as firmly Triassic. The presence of these plant fossils, as confirmed by this study, suggest an extension of the previous assigned age to Late Permian. Results by this study adds to evidence that, during the Permian time, the Gondwana Supercontinent was characterized by Glossopteris floristic province as shown in many palynological records across India and Africa.

FINANCIAL SUPPORT SERVICES TO ARTISANAL AND SMALL-SCALE MINING PROJECTS IN TANZANIA: A CRITICAL EVALUATION

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The government of Tanzania recognizes the positive contribution of the artisanal and small-scale mining (ASM) sub-sector to the growth of the economy. The presence of support services such as financial services is important for a responsible, inclusive and productive ASM sector. This article examined the effects of artisanal and small-scale mining projects and financial support services in Tanzania. The results indicate that although there has been indication of commitment to support the small-scale mining subsector, the government has failed to acknowledge the need of providing continued financial support to local miners. Thus, the neglect of financially volatile small scale mining projects undermines the participation of artisanal small scale miners in the feasible mining activities. It is concluded that a financial scheme suitable for artisanal and small-scale miners should be developed to improve the availability of financial assistance to their projects.

REMOTE SENSING TECHNIQUE FOR RECONNAISSANCE GEOLOGICAL EXPLORATION: CHEAP AND HIGHLY ACCURATE APPROACH FOR MAPPING

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A reconnaissance survey involves target generation at the grassroots level for exploration and in identifying potential existence and extent of mineralization. Usually a team, before embarking on a field visit, needs to evaluate the area and be able to plan the actual exploration strategies. The team also needs to plan work, assess accessibility and topography of the area, literature review and obtaining permits.

The advancement of technology in the current decade led to a more sophisticated way of doing reconnaissance and regional mapping of areas by using remote sensing approaches. There are several advantages of using remote sensing techniques from the large existing database of several datasets including ASTER, Landsat 7 and 8 satellite imagery, SRTM, DEM, etc. The ability to get regional views of large areas, ease of combining information from multiple sensors, availability of sophisticated computer and software, advanced equipment with capabilities for analysis and interpretation is of vital importance in reconnaissance and regional mapping. Apart from satellite sensors, the use of lightweight Unmanned Aerial Vehicles (UAVs) provides a unique opportunity to conduct rapid and non-invasive exploration even in socially sensitive areas and in relatively inaccessible remote areas. Employing drones with hyperspectral sensors to detect surface anomalies and thus contribute to a rapidly evolving field at the cutting edge of exploration technologies.

Remote sensing approaches can be used for the production of reconnaissance geological maps which contain a range of lithological and structural information based on interpretation of several anomalies. Today's wide assortment of sensors allows for overlaying, combining, or even subtracting

sensors in the search for meaningful maps. Spectral signatures of plants, rocks and minerals can be well established, allowing remote reconnaissance to identify areas favourable for energy and mineral exploration or extend such existing prospects. The use of land surface temperature (LST) and Thermal Infrared (TIR) satellite data offers the possibility to detect thermal anomalies which are applicable in geothermal exploration, can also use hyperspectral reflectance data and geomorphic indicators for remote sensing exploration data of structurally-controlled deposits, spatial distribution dyke hosting mineralization, and mafic intrusions.

This contribution aims to show and advocate the applicability of remote sensing on easing the work of geological reconnaissance study and preparation of the field base maps depending on the particular survey to be conducted ranging from all geological fields from structural, mineral exploration, petroleum exploration, energy and geomorphological studies.

ELEMENT CHARACTERIZATION IN THE NAMTUMBO AREA, SOUTHERN TANZANIA: IMPLICATION FOR URANIUM PROVENANCE AND GEOCHEMICAL EXPLORATION

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The most common occurrences of uranium (U) in Tanzania can be found in the Karoo basins located in the southern part of the country, including the Namtumbo - Mkuju river area, Bahi depression located in central Tanzania, Madaba area near Chimala in southern Tanzania. Other occurrences include those of Arusha in the Northeastern part of the country, where U is associated with carbonatites and magmatic lava flows.

We collect 63 samples by auger from a depth of 0 – 3 meters at a 1km x 1km grid sampling interval from the Namtumbo-Mkuju river area and analyze them at SGS Laboratories in South Africa for trace elements using ICP-AES and ICP-MS after AR digest. Duplicate samples were analyzed for both major and trace elements at the Geological Survey of Tanzania Laboratories using XRF energy dispersive technique.

The results show that threshold values variability in percentages (%) within the 3-meter depth interval is the function of element type; that is 0% for siderophiles/lithophile, W; 12% for siderophile/chalcophile, Mo; 10% to 29% for chalcophiles and lithophiles, Cu, Ga, and Sn; 12% to 25% for lithophiles which are HFSE, Hf, and Ta; 4% to 26% for chalcophiles Zn, Pb, In, As, Tb, Bi, Ag, and Cd; 6% to 29% for siderophiles and chalcophiles Co, Fe, Sb, Ni; 5% to 40% for lithophiles V, Cr, Tl, U, Sc, Rb, K, Zr, Cs, Th, La, Yb, Al, Ti, Ba, Ce, Mg, Lu, Y, Ca, Sr, Nb, Li, P, Na, and Be; and 43% for siderophile Mn.

Correlation coefficient (R) of elements with respect to U varies between 0.07 (Ti) and 0.79 (Zn). The dataset show (with exceptions of a few) that

lithophile elements behave both as lithophiles and siderophiles and those which behave both as chalcophile and siderophiles in the crust tend to have relatively high correlation coefficients (R >0.47) with U; as compared to elements that are either chalcophiles or siderophiles only.

Magnitude and trend thresholds of elements vary significantly. For example, U, Sn and Sb have thresholds that constantly increase from surface (first meter) to the bottom (third meter); contrarily to Hf, P, Ca, Zr, Co, Al, Ti, Rb, Sr, Na, Tl, Th, Mn and Cr elements that show decreasing threshold values from surface to the bottom. However, other elements (64% of the data set not listed here) do not have defined trends within the three meters depth. The above results indicate that the source of U in the area is most likely from weathering of igneous related granites like volcanic arc granites; sedimentary granites as well as post-orogenic granites or their metamorphic equivalents. We recommend that the thresholds for these elements can be used as a basis for determination of geochemical anomalies in this area or in other areas with similar geological settings.

2D AND 3D LITHOSPHERE MODEL OF THE SW TANZANIA RIFT SYSTEM, FROM GEOLOGICAL AND GRAVITY DATA

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2D forward gravity modelling and 3D structural geological modelling studies were conducted to constrain the lithosphere structure of the SW Tanzania Rift System. The modelling results were integrated with available data to enable the construction of the first 3D lithospheric model of the study area.

The 3D model shows important variations of both Moho and asthenosphere mantle depths. The reconstructed Moho depth ranges between 21 and 55 km with the shallower depths situated beneath the rift basins, while the deeper Moho is located beneath the Tanzania Craton, the Bangweulu Block and some parts of the Ufipa horst. The Moho depth changes sharply in the Ufipa horst, from shallow in the NW part to deeper in the central part. This change suggests a different setting of the Moho, probably driven by pre-rift tectonics.

The depth of the Lithosphere-Asthenosphere Boundary (LAB) varies within the study region between 98 and 244 km. It is generally shallow along the strike of the rift which suggests that it originates from extensional thinning of the lithosphere. The most interesting finding is the thinnest lithosphere of less than 100 km around the Bangweulu block and a symmetrical wedge structure observed in the NW part of the study area. These findings suggest the existence of a southward directed paleo-subduction zone, probably existing during Neoproterozoic time. The southern Tanganyika Basin and northern Rukwa Basin show relatively thick lithosphere in comparison with the adjacent areas. Because shallow Moho in the region suggests crustal

thinning has occurred, we propose that the relatively thick lithosphere could be the result of crustal magmatic underplating.

As lithospheric thinned zones usually are associated with elevated temperatures, high heat flows, magmatism and active faulting and fracturing, our findings suggest the study area to be a potential target for geothermal exploration. The active faults and fractures provide permeable pathways for hydrothermal fluids to flow from the hot rifted basement into the basins, where the hot fluids can be produced from aquifers.

MINERALOGY AND LEAD ISOTOPES COMPOSITION OF POLYMETALLIC VEIN DEPOSITS OF THE MPANDA MINERAL FIELD IN KATAVI TANZANIA

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The Mpanda Mineral Field (MMF) in the Proterozoic Ubendian Belt SW Tanzania hosts significant polymetallic (Au-Cu-Pb) mineralization in the Katuma Block. The mineralisation occurs as veins that are hosted within faults, fractures and shear zones cutting different rocks including metabasite, gabbro, orthogneisses, metapelite and granites. Most of these rocks formed and metamorphosed in Neoarchean (2.71 – 2.64 Ga) and Palaeoproterozoic (2.05 – 1.84 Ga) Andeantype active continental margins. Geochronological data indicate that these veins together with the surrounding hydrothermal alteration halos in host rocks formed about 1.2 Ga, circa 600 Ma after the Paleoproterozoic Ubendian orogenic event that formed or metamorphosed most of the host rocks. Similarity between the age of vein formation in the MMF within Katuma Block and the age of first metamorphism of the fluids fertile sedimentary rocks of the neighbouring Wakole Block, points to metamorphic origin of the metaliferous fluids causing mineralisation in the MMF within Katuma Block.

Here we present results of Pb-isotopes analyses and detailed studies of ore and gangue mineralogy of the veins in order to characterise the mineralogy of veins and support the metamorphic origin of the fluids and polymetallic mineralisation. The ore and gangue mineralogy results have been studied using petrography and microprobe analyses of representative samples from the MMF. Metabasites and gabbros that are associated with the mineralization contain numerous sulphide bearing veins, the significance and relationship of which with the mineralization is not yet established. Proximal

to the ore bearing veins the amphibolite to granulite facies host rocks show hydrothermal alteration (chlorite ± carbonates ± K-feldspar), muscovite/sericite formation and an increase in sulphide disseminations. Deposits in MMF are significantly weathered, with sap rock reaching up to 20 meters in thickness. Proximal to ore zones, host rocks are pervasively hydrothermally altered, with alteration halo reaching up to several tens of meters wide. Barite is also common and often associated with polygonal granoblastic quartz, disseminated pyrite, chalcopyrite, chalcocite and pyrrhotite proximal to the veins.

The veins show open fill textures, which include euhedral minerals, vugs and crustification, and are composed of coarse grained quartz, k-feldspar, siderite, barite and sulphides mainly galena, pyrite and chalcopyrite. The gangue and ore minerals occur in bands. Gold occurs mainly in or in contact with pyrite, whereas chalcopyrite is associated with emplectite, wittichenite, aikinite. Secondary minerals include covelite and digenite which replaces chalcopyrite, and hematite, secondary quartz, azurite, malachite and copper silicate minerals that form as products of weathering of primary vein minerals.

Lead isotopes data from mineral separates (mainly galena and pyrite/chalcopyrite) from representative ore samples when plotted against the plumbotectonic lead growth curves defined by Zartman and Zoe (1981) most lie in a cluster on the upper crustal curve, in the plot of $^{206}Pb/^{204}Pb$ versus $^{207}Pb/^{204}Pb$. On the plot involving thorogenic ^{208}Pb, the cluster is on the Lower crustal curve; indicating the origin of Pb and other metals from crustal sources. Our results are also consistent with Pb-isotopes data from previous works of the veins.

PALEOCEANOGRAPHIC EVOLUTION IN THE SOUTH CHINA SEA FROM THE UPPER PLIOCENE TO PLEISTOCENE ON THE BASIS OF CALCAREOUS NANNOFOSSIL ASSEMBLAGES

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The calcareous nannofossil assemblages from Ocean Drilling Program Hole 1146A in the South China Sea are studied for the purpose of reconstructing the paleoceanographic conditions, especially changes in thermocline or nutricline depth, from the upper Pliocene to Pleistocene. The study based on the changes of the relative abundance of the upper and lower euphotic zone species (Small reticulofenestrids and *Florisphaera profunda* respectively), warm-water species, productivity index (N-ratio) and annofossil accumulation rate (NAR).

The calcareous nannofossils assemblage changes indicate four long-term intervals of the nutricline/thermocline variation, paleoproductivity and paleoceanographic condition changes in the SCS for the past 2.86 Ma. The co-occurrence of abundant small reticulofenestrids, less abundant *Florisphaera profunda* and warm water species, high N-ratio and NAR suggest increase of productivity and shallowing of nutricline/thermocline depth that led to the enhancement of upwelling system and supply of nutrient on sea surface, a typical eutrophic condition. Conversely, the co-occurrence of low small reticulofenestrids abundance, abundant *F. profunda* and warm water species, low N-ratio and NAR indicate the decrease of productivity and deepening of nutricline/thermocline typical of oligotrophic condition.

The investigated parameters indicate that, for the past 2.86 Ma, the SCS paleoceanographic condition changes from a typical oligotrophic condition

(2.86-1.71 Ma) to mesotrophic (1.71-0.59 Ma) to strong eutrophication condition around (0.59- 0.25 Ma) and gradually changed to oligotrophic condition (< 0.25 Ma). The timing of the eutrophic condition has been linked to the strengthening of the East Asia Winter Monsoon.

TECTONIC EVOLUTION OF SEAGAP FAULT ZONE: IT'S IMPLICATION TO SEDIMENT DISTRIBUTION IN MAFIA DEEP BASIN

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The Sea Gap Fault (SGF) is a nearly N-S trending Mid-Jurassic sinistral strike slip fault, formed as a result of trans-tensional reactivation of extensional Lower Jurassic fault. The objective of this study is to provide understanding of the tectonic evolution of the SGF and its impact on sediment distribution in the basin. Interpretation of the 3D seismic data set was performed using Petrel software to generate isopach maps and fault planes in order to model sediment distribution through time. Orientation of the main SGF, fault splays (Riedel structures) and geometry of the restraining and releasing bends along the SGF determines orientation of the stress fields ($\partial 1$, $\partial 2$ & $\partial 3$) that caused strike slip deformation at SGF.

Four different fault sets were observed: Mid Jurassic Normal Faults that controlled syn-rift disconnected wedge-shaped sediment packages, NNW/N trending SGF that controlled deposition of localized sediment packages along the fault within releasing bend areas, NW-trending Riedel structures that join the SGF at an acute angle and the Upper Cretaceous/Paleogene Trans-tensional faults with flower structures on sea bed. The SGF was reactivated at different deformation phases in Mid Jurassic and Paleogene with effect on sediment distribution along, within and away from the SGF. The study confirms that the SGF controls sediment distribution in the Mafia basin.

IMPROVED DEPTH ESTIMATES OF SUBSURFACE SOURCES STRUCTURES USING 2D/3D MODELING OF POTENTIAL FIELD DATA: IMPLICATIONS FOR HYDROCARBON EXPLORATION

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Quantitative analysis of potential field data is made for the Eyasi-Wembere basin. Several previous geophysical studies in the area were based on qualitative interpretation and two dimensional modelling of the potential data. The 3D modelling of the Airborne Gravity and magnetic done shows errors of hundreds of meters. The main focus of these studies were in mapping geometries of the major lithological and structural units of the shallow and deep subsurface using gravity and magnetic data. The ultimate objective of the model is to understand the petroleum dynamics of the region through mapping interfaces geometries.

Automatic inversions, 2D joint forward modeling and 3D inversion are the major techniques employed. In the absence of density information from well data three inversion were run each from different density contrast to test for the most appropriate sediment density. This is further strengthened by the joint 2D forward modeling of gravity and magnetic data which showed the top of the basement. The basement horizon was modified interactively by using 3D forward modelling.

The quantitative interpretation performed reveals an approximate 3 to 5 km depth of sediment in Wembere sub basin, 4 to 6 km for Manonga and 1 to 4.5 km of sediment in the Eyasi Basin. Several structural features of interest indicating possible areas for hydrocarbon accumulation have been mapped. The shallow depth interface is thought to delineate the low density Fluvio-lacustrine sediments including the rift floor volcanic units and crystalline basement. Our investigation results have improved depth estimates compared to the previous studies which identified areas of high sediment accumulation.

TPDC LABORATORY SERVICES

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Tanzania Petroleum Development Corporation (TPDC) Laboratory was established in 1988 through Norwegian Agency for Development Cooperation (NORAD) funds. It is operated in accordance with good oilfield industry practices. The laboratory provides services to the corporation and other clients while constantly adapting to new technologies for delivery of quality services. Currently, the laboratory is in the certification process for International Standard Organization (ISO).

Since its establishment, the laboratory has offered various analytical services to different International Oil Companies, neighboring countries and research institutions in collaboration with various local and international universities. TPDC laboratory offers a range of analytical services from an outcrop scale, single well, data analyses and interpretations. Currently, the laboratory comprises four sections namely geochemistry, micropaleontology, palynology and petrology. The services provided include Total Organic Carbon (TOC) analysis and pyrolysis, relative age determination, paleoenvironmental settings, thermal maturity and petrographic analysis. TPDC invites all stakeholders in the industry, research institutions, various entities and individuals to use our laboratory facilities and services.

TANZANIA UPSTREAM DEVELOPMENT AND LIQUEFIED NATURAL GAS PROJECT

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Tanzania has made an offshore discovery of about 47.08 TCF of natural gas. Shell Tanzania with its partners Ophir and Pavilion, are contractors for Tanzania Offshore Blocks 1 and 4, whereas Equinor (then Statoil) with its partner Exxon-Mobil, are license contractors for Tanzanian Offshore Block 2. The discovered resource provides an opportunity to monetize via LNG to the international market where proportionality of gas remains dedicated for the domestic uses such as Industries, Power generation, Household uses etc. The Government of Tanzania (GoT) and resource developers intend to commercially develop Tanzanian offshore gas through Liquefied Natural Gas (LNG) project. In order to achieve a cost-efficient project, the Government of Tanzania (GoT) proposes to the IOCs partners for Block 1, 2 and 4 to cooperate in developing a joint "land based" Liquefied Natural Gas (LNG) project.

The Tanzania Gas & LNG project is planned to pass through several decision gates before first gas is produced. The planned phases include: Land/Site Acquisition; Pre-Front End Engineering Design (Pre-FEED); Front End Engineering Design (FEED); Final Investment Decision (FID), Project execution and finally the first gas being produced leading to the first LNG train takeoff. At the moment, the project is at the project foundation phase where site for the project has already been acquired and upstream development concepts studies completed. Completion of the Host Government Agreement (HGA) will allow the project to proceed into the Pre-FEED stage.

Despite completion of the upstream development concepts, there is a sizable challenge presented in developing Tanzanian deep sea fields due to Geo-hazard nature of the seabed and flow assurance caused by chosen

development concept. This abstract will also deliberate the observed challenges and various development variables that need to be considered when assessing the feasibility of the development concepts. These variables include, but are not limited to:

- Long distance to shore which ranges from 100 – 202 km;
- Distance between the discovered reservoirs;
- Distance to gas markets with sufficient size/scale to underpin the quantity of off take required to establish a cost competitive development;
- Offshore bathymetry showing the active and radically distributed canyons from the shore to the deep waters;
- Relative higher water depth (ranging from 1,000 – 2,500m); and
- Flow assurance issues

Notwithstanding the chosen development concept, upstream work is ongoing for synergy creation (between upstream Blocks) and cost optimizations.

PALEO DEPOSITIONAL CONDITIONS OF PERMIAN ORGANIC-CARBON-RICH DEPOSITS OF THE HELGELAND BASIN, OFFSHORE MID NORWAY, BASED ON ELEMENTAL PROXIES AND CORE LOGGING

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Core logging and analysis of elemental proxies have been used to investigate the deposits of parts of the Permo-Triassic System of core 6611/9-U-01 from the Helgeland Basin in the Norwegian Sea. The deposits contain variable amounts of debrites, slides, slumps, high density turbidites, low density turbidites, and ambient and turbidite mudstones. The measured section includes two upper Permian organic-carbon-rich (OCR) intervals within a low density turbidite-dominated sequence, and elemental proxies have been used to determine their depositional conditions. Element concentrations were measured using a portable X-ray fluorescence scanner. Measurements of 23 elements have been linked to grain size distributions and flow process variations. Results show that the analysed interval contains four major fining upward cycles dominated by gravity flow deposits. The combination of elemental distributions and facies suggests that the OCRs were formed during periods of anoxia and low particulate gravity current activity. The upper OCR interval was deposited in a basin that received significant input from fluvial sources where the fluvial overflow caused water column stratification and anoxia. The study also shows that environmental conditions of organic-carbon-rich intervals can be identified in a basin where this signal is mixed with the element signal caused by variations of grain sizes.

THE ANOMALOUSLY-PROPAGATING SOUTH KENYA RIFT IN THE CONTEXT OF THE NORTH TANZANIAN DIVERGENCE ZONE, EAST AFRICA

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The axial fault-bounded depression of the South Kenya rift (SKR) locally displays anomalously wide sectors resulting from the presence of one (or many) elevated and offset block(s) on the flanks of the main trough. Very little attention has been paid so far to the nature of the driving mechanisms responsible for these atypical rift patterns. New insights are supplied by the Natron-Ol Doinyo Ogol rift segment at the southern extremity of the SKR, immediately north of the North Tanzanian Divergence (NTD). On the basis of interpreted SRTM-30 satellite imagery and Digital Elevation Models, our work allows us: i) to depict the highly-segmented arrangement of the ~7 Ma-lasted SKR system, ii) to establish a two-stage kinematic rift model that emphasizes the role of an inherited transverse discontinuity on the arrest, as well as lateral jump and off-axis development of anomalously-propagating rift structures, iii) to define the relative contribution of border vs inner fault networks to the total extension, which is estimated at 7–6 km (11.6–9.2%), and iv) to emphasize that inner faulting was not the dominant mode of strain accommodation during recent inward focussing of strain, and that no sharp transition exists from border fault- to intra-rift fault-dominated strain accommodation over time in the SKR immature rift system.

ANALYSIS OF THE NEOGENE SEDIMENTS FROM EYASI-WEMBERE BASINS, NORTHERN EASTERN TANZANIA

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The aim of this study was to investigate palynomorphs in rock samples in order to identify, date, and comments on depositional environment and thermal maturation of the palynomorphs from three stratigraphic boreholes drilled in Eyasi-Wembere Basin in the Northeastern Tanzania. Forty-three core samples from the Eyasi and Wembere sub basins (Kining'inila-1, Nyalanja-1and Luono-1 boreholes) have been processed and analysed for their palynological contents.

The sample yielded fair to well preserved terrestrial palynomorphs while other samples were barren. Thirty four terrestrial species were identified and systematically described from which mostly abundant species were recovered from pollen grain. In addition, species from Chlorophycophyten algae (Botryococcus sp), and various fungal fruitifications were observed.

The palynomorph assemblages are used in a Palynostratigraphic age assignment based on comparisons with previously developed biozones for the Neogene of Gondwana. The recognized palynomorphs suggest Miocene-Holocene age for the Eyasi-Wembere Basin. Palynofacies analysis carried out and used to reconstruct paleoenvironment revealed existence of shallow, pond- or lake-like aquatic, wetland depositional environments. High abundance of amorphous organic matter in some of the studied samples suggests low energy, dysoxic-anoxic environment. Maturation studies based on spore color index indicate that the organic matter in the studied core samples were mature for hydrocarbon generation.

MINING PROJECTS FINANCING - GENERAL PERSPECTIVE

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Mining projects are capital intensive. The capital could vary from tens of thousands to tens of billions of US dollars (US$) depending on the scale of operations. Small-scale operations' capital could be in ranges of tens of thousands to millions of US$, whereas medium scale mining projects' capital may range from tens of millions to hundreds of millions of US$. On the other hand, capital for large scale mining projects could range from hundreds of millions to tens of billions of US$.

The intensity of capital in mining projects does not only depend on the scale of operations but also other factors in play. For instance, depending on where the minerals are found, if they are found deep in the underground may require underground operations which are usually capital intensive compared to minerals found near the Earths' surface which usually require open-pit operations. Other factors include the type of mineral and the mineral characteristics, its chemistry and complexity. Generally, metal related projects are capital intensive compared to mineral industry or construction mining projects.

Because mining projects are capital intensive, a firm or a company involved in mining operations need to find means to raise capital. A firm or a mining company could raise finance for mining projects at any stage of the mining value chain: from non-producing or undeveloped mining licenses (not yet explored geologically) to mine producing projects (active or operating mines).

This abstract presents how a firm or a company can raise finance for mining projects. It discusses two main types of financing mineral projects. The traditional ways, which is equity and/or debt financing, and secondly, the new approaches involving royalty financing and metal stream purchases. It also deliberates opportunities to raise finance for mining projects in

Tanzania, in particular through Dar Es Salaam Stock Exchange (DSE) and money markets.

THE ORIGIN OF HIGH HELIUM CONCENTRATIONS IN THE GAS FIELDS OF SOUTHWESTERN TANZANIA

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Volatile elements are concentrated at Earth's surface, forming a rich atmosphere and oceans which enabled the eventual emergence of life. However, volatiles are also abundant in solid Earth reservoirs, such as the crust and mantle, and these reservoirs play a key role in moderating volatile movement throughout the planet. Continental cratons represent a potentially large, yet under-constrained volatile reservoir. When cratonic regions are catastrophically disrupted by large volcanic and/or rifting events, they release massive amounts of volatiles into Earth's atmosphere on geologically-abrupt timescales (e.g., Lowenstern et al., 2014; Muirhead et al., 2020). Here, we report gas data (He-Ne-N_2-Ar-CO_2) from seeps along the flanks of the Tanzanian craton, within the western branch of the East African Rift System (EARS) - a region where the stable continental craton is actively being broken apart by rifting and simultaneously heated by plume-induced volcanism. Bulk gas and noble gas isotopic data are reported in seeps from three regions: 1) the Rukwa Rift Basin (RRB), 2) the Lupa Hydrothermal System (LHS) and 3) the Rungwe Volcanic Province (RVP). Seep gases from the RRB are dominantly comprised of N_2 and He, with >90% N_2 concentrations, high ^{4}He concentrations (2.4–6.9%) and radiogenic He isotopes (0.16–0.20 R_A). Seeps in the LHS - located between RRB and RVP - are characterized by little-to-no N_2, high CO_2 contents (72–84%), relatively low He contents (0.008–0.15%), and higher ^{3}He/^{4}He (0.95–0.99 R_A). RVP

gases have high CO_2 (78%) and low ^{4}He (0.0003%) and more mantle-like He isotopes (3.27–4.00 R_A) consistent with previous findings (Pik et al., 2006; Barry et al., 2013). All neon isotopes can be explained by mixing between air, high O/F crust and depleted Mid Oceanic Ridge Basalt (MORB) mantle-like signatures. RVP neon isotope seep data potentially suggest a solar-like deep mantle contribution, consistent with findings in rocks from the area (Halldórsson et al., 2014), however we note that this signal is difficult to discern from mass dependent fractionation (MDF). The largest $^{40}Ar/^{36}Ar$ anomalies occur in RRB, with resolvable excess ^{40}Ar derived from radiogenic production in the crust. Using a noble gas solubility model, we calculate volumetric gas to water ratios (V_g/V_w) and show that V_g/V_w values are low for RRB (0.1), consistent with longer migration distances, whereas V_g/V_w are higher for LHS ($V_g/V_w = 0.1–10$) and RVP ($V_g/V_w = 3–12$), suggesting a more direct conduit for volatiles from source to surface. In summary, these data demonstrate interaction between two distinct helium sources, one of which is crustal in origin (most prominent in RRB) and the other being mantle-derived (enriched in RVP). The extent of mixing between the two is shown to be influenced by proximity to rift-related fault structures, groundwater interaction and magmatic heat.

OVERVIEW OF PETROLEUM SUB-SECTOR IN TANZANIA, TANZANIA PETROLEUM DEVELOPMENT CORPORATION PROJECTS

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Exploration activities in Tanzania commenced in the 1950s and in 1974, the first gas discovery was made over Songosongo Island, followed by another discovery in 1982 in Mnazi Bay. Since then TPDC has continued to conduct exploration activities in partnership with International Oil Companies (IOCs) through Production Sharing Agreements (PSAs).

Currently, there are ten (10) active PSAs; Seven PSAs (Block 1 & Block 4, Block 2, Ruvu, Ruvuma, Nyuni and Kilosa-Kilombero) are under the exploration phase and three PSAs (Songosongo, Mnazi Bay and Kiliwani North) are under production phase. To date, 57.54 TCF (GIIP) has been discovered in both onshore and offshore basins of Tanzania. The gas produced from onshore reserves is used for industrial, household and electricity generation, while offshore gas resources will be developed through Liquefied Natural Gas (LNG) project with domestic obligation.

TPDC is fully engaged in commercial aspects of petroleum in the whole value chain as a National Oil Company following the enactment of the Petroleum Act, 2015. Under upstream operations, TPDC is conducting exploration activities in Mnazi Bay North, West Songosongo, Lake Tanganyika North, Eyasi Wembere and 4/1B Blocks. Currently, exploration activities in these Blocks are in different stages of geological and geophysical studies. TPDC continues with hydrocarbon exploration activities in the country and encourages potential investors to work with TPDC in oil and gas exploration and development.

HYDROCARBON SOURCE ROCK POTENTIALITY IN RUVU BASIN: A CASE STUDY FOR MIDDLE JURASSIC -BAJOCIAN SHALE

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Ruvu Basin is located in the eastern part of Tanzania and formed as a result of rifting related to the break-up of Gondwanaland in the Permo-Triassic. During the Middle Jurassic, the basin evolved as a passive continental margin associated with deposition of Bajocian shales encountered in Well-1 at 250 – 325 m depth and Well-2 at 2580 – 2663 m depth. The intersected shale have lateral extension within the basin with an increase of the burial depth towards the basin center. The cuttings of the Bajocian shales intersected in the Well-1 and Well-2 wells above were assessed for source rock potentiality through geochemical analysis (Pyrolysis and Total Organic Carbon (TOC), Biostratigraphic (Palynomorphs) & sedimentological (facies) studies.

Results show that the source rock facies are characterized by the presence of thin layers of carbonaceous shales, pyritic shales, argillaceous and, patches of coaly matter with restricted fauna (Posidonia and ammonites) indicating poorly oxygenated bottom conditions. The facies depositional environment is an inner shelf with a reducing environment and strong terrestrial influence due to the presence of land-derived palynomorphs. The geochemical evaluation of the cutting indicated TOC values ranging (2.27- 4.97) wt. %) displaying a good source rock and Kerogen Yield (S2) of (2.33-8.87) mgHC/g signifying a fair to good hydrocarbon generation. The Bajocian shale matured to the oil window has mostly displayed a mixed kerogen type II and III and dominantly a terrestrial origin.

Generally, the Bajocian shales have shown the best source rock potential for oil and gas at optimum maturities. The Bajocian shales at Well-1 indicate

maturation at shallow depth, suggesting a substantial uplift and erosion. However, the analysis of the lateral extent established from the maturity maps shows that the area is critical for hydrocarbon exploration.

OPTIMIZATION OF 2D SEISMIC SURVEY DESIGN IN EYASI-WEMBERE BASIN USING 2D/3D MODELING OF POTENTIAL FIELD DATA

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Eyasi - Wembere basin is in northern Tanzania within the East African Rift System. The basin is subdivided into Natron, Engaruka, Manyara, Eyasi, Wembere, and Manonga sub-basins. In 2016, TPDC Acquired Gravity Gradiometry data in order to estimate sediment thickness, delineate the basin and understand the basin architecture/structural configuration prior to seismic survey design. Qualitative interpretation of the Gravity Gradiometry data using different filtering and enhancement techniques has revealed the presence of narrow rift grabens in the Central and Western parts of the basin. The mapped sub-basins were observed to be developed in the crystalline basement with the NE-SW and NW-SE trending major bounding faults which control sedimentation. The quantitative interpretation was carried out using p-depth, inverse modeling, and forward 2D/3D modeling techniques. The interpretation revealed the extent of sediment thickness that is enough to generate oil or gas if thermal conditions are favorable. The enhanced mapping of the anticipated geological target structures is useful inputs to design 2D Seismic survey layout and parameters.

THE SEDIMENTOLOGY AND STRATIGRAPHY OF THE MESOZOIC SUCCESSIONS FROM THE ONSHORE TANGA AND RUVU SUB-BASINS, NORTH-EASTERN TANZANIA

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Tanga and Ruvu Sub-Basins are controlled by the NE-SW trending Tanga fault to the North-Eastern Tanzania. To the West both are bounded by the Neoproterozoic metamorphic basement of the Mozambique belt, whereas to the South-East the Tanga Sub-Basin is bordered by the Ruvu Sub-Basin and the Ruvu Basin itself is bordered by Dar Es Salaam platform. Both basins to the West are adjacent to the N-S trending Tanzania Coastline.

Tanga and Ruvu Sub-Basins are an outcome of the south-west opening of the Somali Channel during Jurassic Period, of which the propagation failed, as due to an eastward shift of extensional stress fields. This opening gave rise into several isolated Normal Faults that controlled the Coastal Basins of Tanzania of which Tanga and Ruvu Sub-Basins are among. Regionally, the Gondwana Rifting events occurring during Permian continued up to Early Jurassic resulted into several intra-continental basins mostly affecting the Proterozoic Mobile belts. This had an impact to controlled sedimentation and depositional environments.

In Tanga Basin, the Tectono-stratigraphy started in Early Jurassic where the rifts created accommodation space for continentally derived clastics of Karoo. The Early Jurassic Lower Karoo is consisting of poorly sorted conglomeratic sandstones sitting unconformable over dolomitic marble and the gneises in some parts as the basement rocks. The organic rich and ferruginous shales (Tanga Beds) make up the thinly laminated fissile beds with fossil prints of Mid Karoo sequence whereas the Upper Karoo section on top are the fluvial system that intervened to deposit the fining up sequence of finely laminated, cross bedded sands and coarser sandstones thin to thicker

inter-beds commonly outcropping at Kidugalo-Ngerengere area and Tanga-Horohoro road cut. The fluvial systems are of good quality reservoir, silica cemented sandstones. Some localized rollover anticlines, pinch-outs, faults and folds of which are regionally potential elements for hydrocarbon system are recorded in the upper Karoo section.

During Mid Jurassic, the Basin was subject to shallow marine depositional environment depositing an extensive fossiliferous carbonates which today outcrop as karsts commonly known as Amboni Limestones, outcrops at Msolwa-Lugoba and Msata areas. They also form as isolated mounds/hills that overstep and overly the basement unconfomably e.g. the Tonga and Chikumbi, Chankulu hills that are manifested on the surface along the flanks of Chalinze (Msolwa) – Lugoba - Msata highway occurring as a result of reverse reactivation of the older extensional Ruvu-Tanga fault during Upper Jurassic.

The Cretaceous sandstones are commonly exposed on the surface at Pera area in Chalinze area and were intersected by Ras Machuis exploration well in the NE Tanga. In both Sub-Basins, the fluvial system pre-dominates during Cretaceous depositing Sandstones, silt and mudstones.

THE TECTONIC FRONT AND SOUTHERN EAST AFRICAN OROGEN OF TANZANIA: HIGH-GRADE METAMORPHIC BELTS WITH POTENTIAL FOR HOSTING SIGNIFICANT AU AND NI, CU, PGE COMMODITIES

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Advances in understanding the geologic-tectonic framework of the Precambrian Shield of Tanzania invoke on the extension of the Archean Tanzania Craton into the Southern East African Orogen (SEAO), prior to the ~1.8-2.1 Ga Usagaran and ~640-560 Ma Pan-African Orogenies (Fig. 1). This Orogen comprises three tectonic zones: 1) the Tectonic Front Zone of reworked Archean craton margin, Paleoproterozoic foreland basins of volcanic-sedimentary rocks, thrust-transported and obducted ophiolites and eclogites (e.g. Konse and Ndembera Groups0; 2) the Central Tectonic Zone of reworked Archean granitoid-gneiss and migmatite (e.g. Usagara-Ukaguru and Mbulu-Masai Superterranes) tectonically sutured by the largely amphibolite facies igneous-sedimentary rocks (e.g. Mkurumu-Magamba Terrane) in the Kilindi Handeni Superterrane; and 3) the Eastern Tectonic Zone of curvilinear arcs of high-pressure felsic-mafic gneisses and granulites, thrust-transported marbles and quartzite (e.g. Neoproterozoic Eastern Granulite and Uluguru-Pare Superterranes).

Qualitative interpretation of remotely-sensed images, follow up mapping prior to systematic exploration and research activities conducted in the SEAO further revealed existence of regionally-extensive, E-W-trending synformal-antiformal mafic amphibolite in para-/ortho-gneisses. The latter are preferentially overprinted by strong NW-SE-trending shear-foliation cross-cut by NE-SW-trending mylonitic zones. The latter comprises corridors of intermittently deformed and metamorphosed mafic amphibolite and ultramafic rocks, some with interlaminations of sulphidic quartz-silicate veins, that are host to significant gold mineralization in the Mkurumu-

Magamba Terrane, for example. Intensive prospecting and exploration conducted between 2003 and 2011 by several companies and individuals revealed the discovery potential pertaining to the Mkurumu-Magamba Province in the Kilindi-Handeni Superterrane, including but not limited to: 1) the ~730,000 Oz of indicated and 292,400 Oz of inferred gold resource discovered by CANACO from Magambazi prospect; 2) a significant intercept of 6.62m @ 4.49g/t Au intercepted by AngloGold Ashanti's drill hole VJDD002 from Mkurumu prospect; 3) significant intercepts of 23m @ 2.27g/t Au from drill hole KWBDD010, and 16m@ 6.4 g/t Au from drill hole KWBDD017 drilled by Dhahabu Resources (Benzu) from Negero prospect, among others (Fig. 2).

Relatively juvenile mafic-ultramafic rocks superimposed on to the SEAO/Archean Craton margin, (e.g. coincidentally high-magnetic anomalies and copper-nickel in soil anomalies in the Kongwa Domain: Fig. 2), possess high potential of hosting significant Au and Ni, Cu, PGE deposits. This is speculated on the basis of their similarity, at least in terms of geologic-tectonic setting, to the Albany-Fraser Belt, east of Yilgarn Craton, Western Australia and Grenville Province east of the Abitibi-Wawa Archean Craton

In can be concluded that exploration results, especially the significant drill-intercepts so far returned from Kilindi-Handeni Goldfields, in conjunction with the very recent past global discoveries such as: 1) the >100 t Au Tropicana in the Proterozoic Albany-Frazer-Musgrave Mobile Belt in the south-eastern margin of the Archaean Yilgarn Craton, Western Australia (Doyle et al., 2009); 2) >10 Moz Au Plutonic deposit hosted by Paleoproterozoic-reworked Archean rocks (Capricorn Orogen) in the NNW-strike extension of the gold-rich Eastern Goldfields, Yilgarn Craton, Australia; 3) potentially metamorphosed, >150 t Hemlo gold deposit in the Wawa Belt, Superior Craton, Canada, situated along strike from the gold-endowed Abitibi Belt (Tomkins et al., 2004); 4) the >15 t Au Challenger gold deposit in the Paleoproterozoic granulite-facies reworked (Sleafordian Orogeny) ~2800-2550 Ma greenschist-amphibolite facies Christie Domain in

the Gawler Craton, South Australia (Tomkins et al., 2004) provide invaluable confidence not only to our local prospectors, but local and international junior and large-scale exploration companies to swarm specific terranes in the SEAO looking for Au, Ni-Cu (± PGE) among other mineral commodities.

Terranes prospective for reworked orogenic gold deposits are likely to be those that lie in close geographic proximity to and extension of the gold-rich Lake Nyanza Superterrane (Mkurumu-Magamba Terrane), whereas those prospective for Ni-Cu (± PGE) are likely to be associated with mafic-ultramafic rocks along the cratonic margins (e.g. Kongwa Domain and Mpwapwa Terrane) and further east in the Kwamkono Domain (Figure 2).

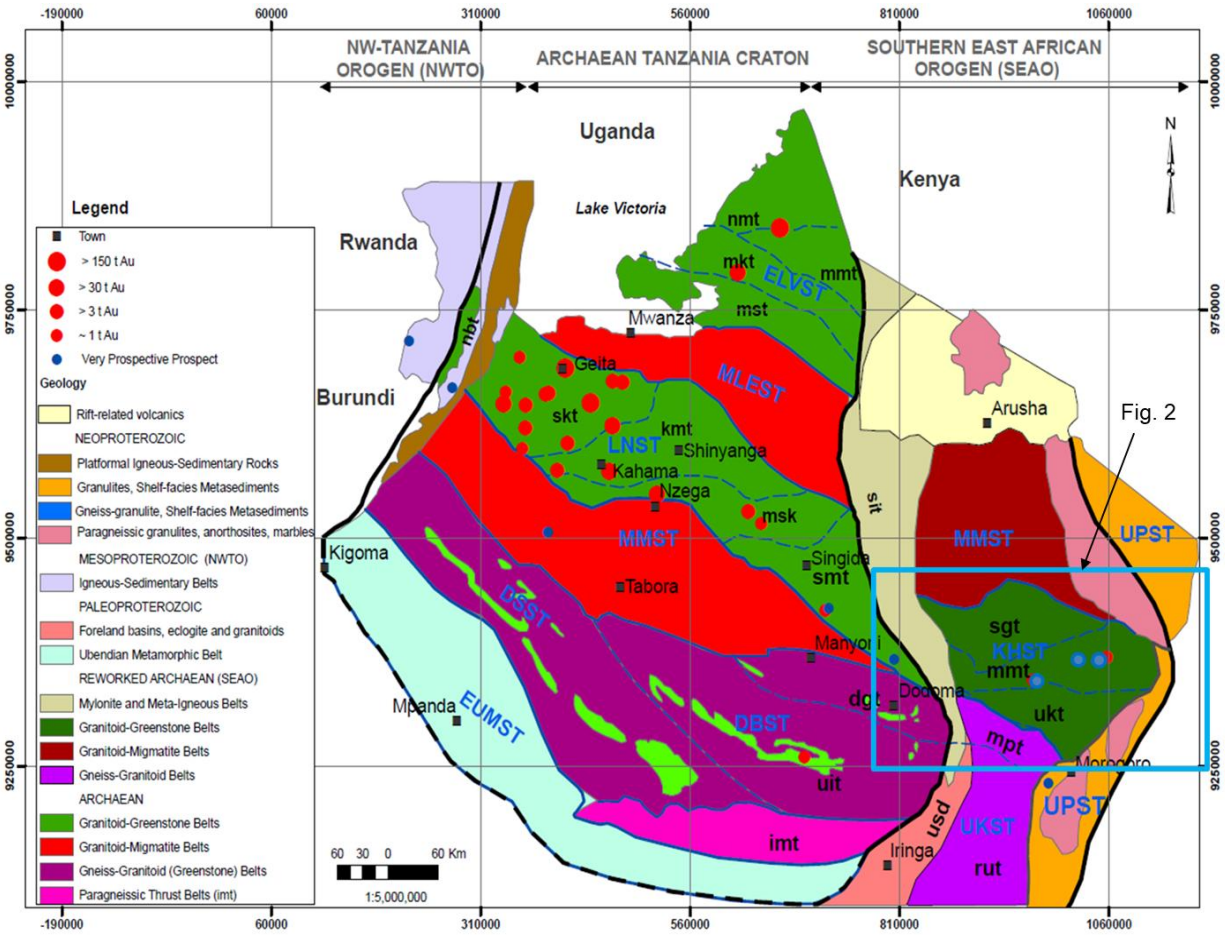

Figure 1: Regional geologic-tectonic setting of the Archean Tanzania Craton and part of the Southern East African Orogen illustrating gold exploration and discovery potential in specific crustal blocks.

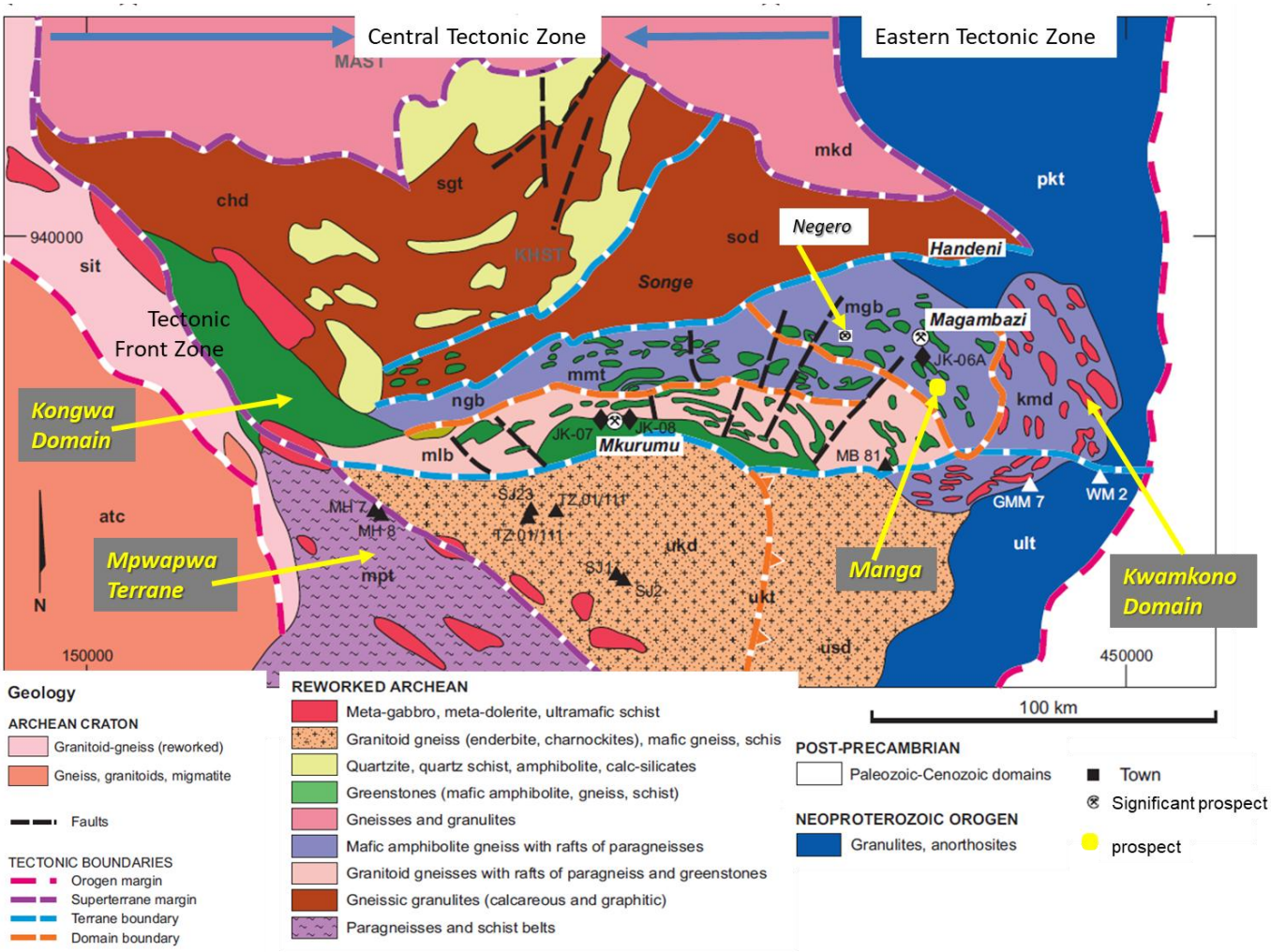

Figure 2: Solid geology of the Archean Tanzania Craton margin, tectonic front and central and eastern zones illustrating prospects that have so far been drill tested and found to contain significant gold mineralization.

THE TAX REGIME AND GEOLOGY EXPLORATION INDUSTRY IN TANZANIA

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Geological exploration is an initial stage in search for and obtaining the desired mineral deposits prior to commencement of mining activities. It covers three major stages from initial prospecting to exploration for mineral deposits and finally mining exploration. In all stages a company experiences continuous cash outflows with no returns, on prospects of hitting a targeted deposit. As such the exploration industry is investment sensitive requiring a vast initial capital injection, most of which is treated more of a gamble on expectation of hitting a mineral deposit. Therefore, one is forced to carefully consider all the risks and factors that cut across geological exploration ventures prior to making a daring decision of procuring that prospecting licence. These include finances, legal and taxation requirements i.e tax rates, policies and available incentives before making that calculated risk. While the first is reliant on the investors' capacity, the second and third items are completely reliant on the fiscal and regulatory environment and are therefore the major bottleneck or incentive to proceed with such projects. As such a country seeking to attract exploration and exploitation of geological resources needs to ensure an attractive and enabling environment is in place.

The current tax regime has in place various tax provisions that should be of consideration to any explorer or mining entity seeking to lay an anchor in the country. Some of the key legislations guiding the industry are; Mining Act 2010, The Written Laws (Miscellaneous Amendments), The Natural Wealth and Resources Contracts (Review and Re-Negotiation of Unconscionable Terms) and The Natural Wealth and Resources (Permanent Sovereignty) Acts of 2017, the Mining (Local Content) Regulations 2018 and the Mining (State Participation) Regulations, 2020. In addition, there are specific

provisions for the extractive sector under the Income Tax Act (ITA), 2004, as well as general tax provision from the Value Added Tax Act (VAT), 2014 and Stamp Duty Act, 1972 that affect mining investments just like any other inbound investments.

Some of the key considerations that a large scale mining/ exploration company seeking to invest in Tanzania should be aware of are; Change in control provisions under the ITA, 2004, brought by the Finance Act, 2012, which entails that a when a Tanzanian company having a change in the underlying ownership by more than 50% (for example by sale of shares in a holding company), then there is a possibility of corporate income tax arising on gain deemed from realisation of a company's assets and liabilities. "Farm-in arrangements" which are key in exploration and mining regimes are likely to be treated as a disposal of an investment asset and could result in worse adverse tax implications if future costs in mining projects are regarded as part of a sale of an interest in the mining licence and hence subjected to tax. The government's right to hold from 16% up to 50% of non-dilutable free carry interest shares in the capital of a mining company is another important factor to consider. There are also royalties (currently at 6%) and tax on dividends to investors (at 10%) that are viable factors. This is an overview of taxes directly and indirectly impacting the exploration and mining industry however, the effects could be discussed in a broader spectrum. This study therefore aims at in-depth analysis of how the current tax regime affects the exploration environment and how it influences companies seeking to invest in exploration activities. It further investigates and suggests approaches to adapt in this regime as compared to other tax efficient regimes in the world in order to maintain sustainable development of the mineral exploration and extraction sector.

COMMERCIAL BANKS CONTRIBUTION TO SMALL SCALE MINERS TO ACCESS FUNDS

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Commercial banks are financial institutions which perform the function of accepting deposits from the general public and giving loans for investments with the aim of making profits. Despite the fact that mining operates at levels of physical, commercial and political risks that are significantly higher than those of other industries, still commercial banks can provide credit to small scale miners in order to finance mining, processing and related operating equipment.

Small scale miners should form formal and legal groups with KYC documents such as business licence, Tax clearance, TIN, environment assessment certificate as well as Licence for mining. It is difficult for commercial banks to enter into finance agreement with operations that lack legal status. It is important for miners to start operating accounts with banks as it is safe and an easy way of saving money and also enable them to have access to their funds through banking services such as mobile banking systems. Operating bank accounts help during the process of loans seeking for working capital as always the existing customers are favoured the most and it is through bank statements where the power of lending is established. They should also keep records of their finances which are essential in analysing and evaluating financial inclusion.

Commercial banks have various products and schemes to support the small scale miners such as Asset financing for mining tools where by loans is given to facilitate the acquisition of the equipment and at the same time depending on the value the purchased equipment can also be used as a collateral. Banks also providing the link between the sellers of mining equipment on one hand and miners on the other in such a way that lender does not provide hard cash

to them but it helps them acquire the necessary working tools, hence improve productivity.

He, Ne, Ar AND CO_2 SYSTEMATICS OF THE RUNGWE VOLCANIC PROVINCE, TANZANIA: IMPLICATIONS FOR FLUID SOURCE AND DYNAMICS

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Volatiles, such as carbon and noble gases, are continuously degassed from Earth''s mantle and crust to Earth's surface in continental rifting systems. Here, we present He-Ne-Ar abundances and isotopes as well as major gas chemistry (CO_2, He, Ar and CH_4) data for (n = 13) naturally-degassing seeps in the Rungwe Volcanic Province (RVP) of the East African Rift System (EARS) in south-western Tanzania, Africa. Helium isotopes ($^3He/^4He$) suggest that trace gases are derived from mantle sources, with moderate crustal additions, in agreement with previous studies from RVP (e.g., Pik et al., 2006; Barry et al., 2013). Samples broadly fall into two groups: 1) dominantly mantle-like, with $^3He/^4He$ ranging from 5.2–6.3RA, which can be explained by release of magmatic volatiles, and 2) those with slightly lower 3He/4He (3.0–4.1RA), representing more 4He (i.e., crustal) additions. Furthermore, we report the first Ne and Ar isotopes from RVP, which show $^{20}Ne/^{22}Ne$ from 9.67–10.0 and 40Ar/36Ar from 301.2–412.2, respectively, which are broadly air-like. We employ a solubility degassing model to show that elemental ratios ($^4He/^{40}Ar^*$, $CO_2/^{40}Ar^*$ and $CO_2/^3He$) in the gases can be explained by variable extents of open and closed system degassing from a melt with an initial mantle-like composition. However, we note that $CO_2/^3He$ observations require additional carbon assimilation, likely derived from the thick nearby cratonic crust.

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