International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 1 Issue 8 ǁ Dec 2013 ǁ PP.48-55

A Review of Engineering Geology in Tanzania

Keneth Lupogo
(Department of Geology, College on natural and applied science/ University of Dar es salaam, Tanzania)

ABSTRACT *: Tanzania is situated in geologically active region and hence it is subjected to various earthquake and volcanic related hazards. Other factors such as high annual rainfall and intense weathering when combined with earthquake and volcanic related hazards makes Tanzania an extremelychallenging and interesting environment for geological engineers. This paper reviews the contributions of engineering geologist in the planning and construction of major civil and mining engineering works in Tanzania. These contributions to civil and miningengineering works include: seismic hazard analysis, slope stability analysis, mining and urban planning.*

Keywords *–engineering, geology, slope stability, Tanzania, mining*

I. INTRODUCTION

Tanzania is one of countries with most complex and unique geological setting on earth. The geology and related mineral and mining industry have resulted in the economic development of Tanzania. However, the development of mining industry and the associated infrastructure has taken place;many geological problems related to adverse climatic, topographic and engineering geologic condition have been encountered. These problems have beenalso encountered in other areas of urban development and exploitation of hydroelectric power where considerableinput from the geologic engineers was required.

The importance of engineering geology in the development of Tanzania has somehow been recognized. Most mining schemeshave geological engineer/geotechnical engineer and there is an engineering geology unit within the Geological Survey of Tanzania. The University of Dar es Salaam also offers courses in engineering geology, with an emphasis on geological engineering, to undergraduate geology students.

This paper presents a brief review of geological history of Tanzania and the associated engineering geological problems which affected various engineering projects. Some of the factors influencing engineering projects within Tanzania include rugged topography, high annual rainfall, intense weathering and seismic activity.

II. GEOLOGY

Tanzania is situated in the southern part of east African rift system. Numerous studies on tectonics of the region have shown that there are many mechanism for rifting and the tectonic history of rifting is quite complex (Dawson, 2008). On regional scales four major tectonic provinces have been recognized: the western system (Ubendian system), central system (Tanzanian craton partial covered by Dodoma system), mobile Usagaran system and eastern continental and marine sedimentary rocks of Lower Jurassic to Quaternary, figure 1. The stable Tanzania craton consist of Archean rocks which are granitic complexes, Dodoma system and greenstone belt. The eastern extension of this underlies Mozambique belt contained deformed metasedimentary rocks and intrusions.

This area is characterized by folds and thrusts verging eastward from the orogenic belt. The same characteristic are obtained in Ubendian system. Ubendian system comprises of high grade metamorphic rocks of sedimentary and igneous origin. The rocks include granulite, amphibolite, migmatite, gneiss, schist, quartzites and marble. The metamorphic grade of Ubendian system is mainly amphibolite or granulite facies. The usagaran system contains rocks of Paleoproterozic age that were deposited in geosynclinals troughs. The usagaran system comprises sedimentary rocks and volcanic rocks. In the coast regions and in the parts of the rift, the Mesozoic rocks occur. The Mesozoic sedimentary rocks are alternating transgressive and regressive sequence. The rocks comprises of sandstones, siltstones, mudstone, coral limestones and silty shales. The Cenozoic period consist of sediments and volcanic eruption occurred in several parts of Tanzania. The Neogene volcanic which most occur within East African rift valley overlie Precambrian rocks in the southwest and north eastern part of the country. The quaternary period is characterized by deposition and erosion cycles related to mainly sea level, climate changes and tectonics.

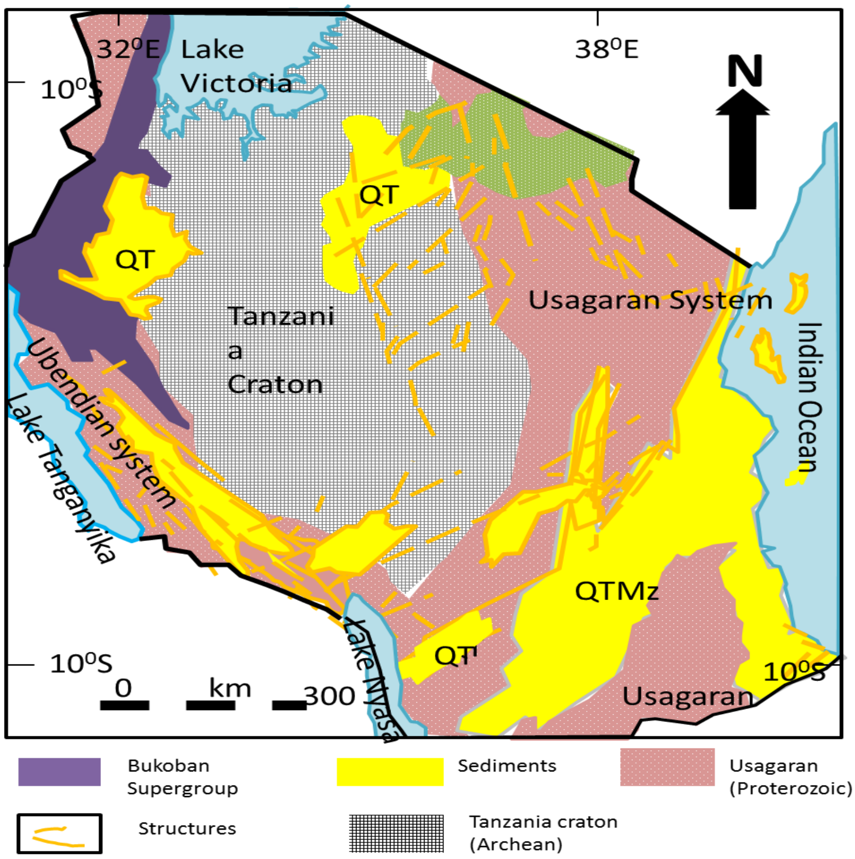

Figure 1. Simplified geological map of Tanzania (Modified from Hester, 1998)

III. SEISMIC HAZARD

The high level of tectonic activity in east Africa rift valley (in Tanzanian part) is major factor in engineering. Earthquakes of magnitude of greater than 5 on the Richter scale are not uncommon within EARS (Daudi, 2007; Msabi, 2010).The urban areas of Arusha , Dodoma and Babati town are located along the eastern branch of the East Africa Rift System (EARS) in Tanzania and are affected by moderate (for magnitude between M5-M6) strong to moderate strong earthquakes (for magnitude greater than M5). In this area, current records contain several earthquakes in the period of 2000-2010 with magnitude greater than M 5.0 (range of earthquakes). The consequence of these earthquakes in this area has necessitated the need for a careful analysis of seismic hazard, including site effects.The seismic source relevant to the these area are moderate to strong shallow earthquakes randomly occurring at epicentral distance of less than 300 km around the cities and towns as shown in figure 1. The study by Daudi (2007) and Msabi (2010) defined tectonic provinces in the area along northeastern Tanzania namely Manyara zone, Eyasi, Kondoa, Natron – Magadi and Pare. A recent work by Msabi (2010), characterized the seismic sources in the area as fault and fault zones. In this work, three active faults and fault zones were identified. The active faults are in Natron and Eyasi basins and fault zone are within Manyara basin, Kondoa, Kwamtoro and Balangida blocks.

The spatial distribution of seismic sources in the area with respect to locations of these urban areas indicates that most of the source generated frequencies may be able to reach the sites with significant amount of energy. The presence of different thickness of sediments within the mentioned sites will act as filter to incoming strong motion frequencies and hence predicting the amplification. The urban areas of Arusha and Babati are mainly covered by various volcaniclastic deposits overlying metamorphic rocks of NeoProterozoic Mozambique belt as basement, whereas the Dodoma municipality is mainly covered by intrusive granites of an Archean age and partially by loose sediment deposits. The thickness of the sediments for the urban areas of Arusha and Dodoma and Babati have not been compiled, but estimates based on ground water investigation show 200 m for the urban area of Arusha and Babati and 10 m for Dodoma.In recognition of this, effort are made to divide the country into major earthquake zones and contoured in terms of seismic intensity (Ferdinand and Nderimo, 2007). Todate, the microzonation for earthquake hazard has been done based on available data from geological maps, global shear wave velocity and remote sensing data.

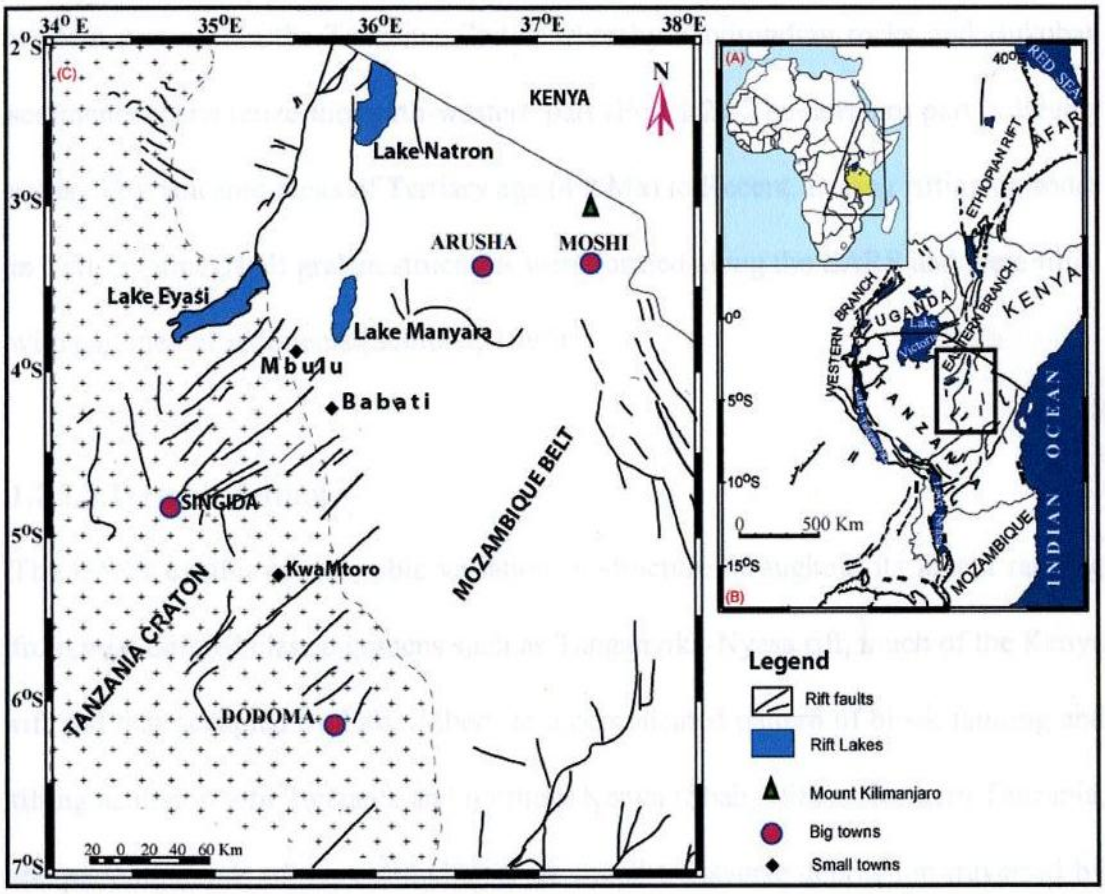

Figure 2; Map of the Tanzania segment of Eastern Branch of EARS (Daudi, 2007)

Recently, efforts have been made by Lupogo et al (2013) to undertake preliminary studies on seismic site effects of these urban area based on qualitative microzonation method developed by Noack and Fäh (2001).This method is based on parameters that qualitatively characterize the local soil conditions and the expected influence in amplification during the earthquake, such as consolidation of the soils, type of the Quaternary sediments, sediment thickness and the lateral variations of the thicknessdetailed description of the scheme is given in Noack and Fäh (2001), this method was used to investigate the earthquake amplification for the urban area of Dodoma, figure 3. Results from this study are promising and more studies such as geophysical and numerical studies are planned to quantify results obtained by this method.

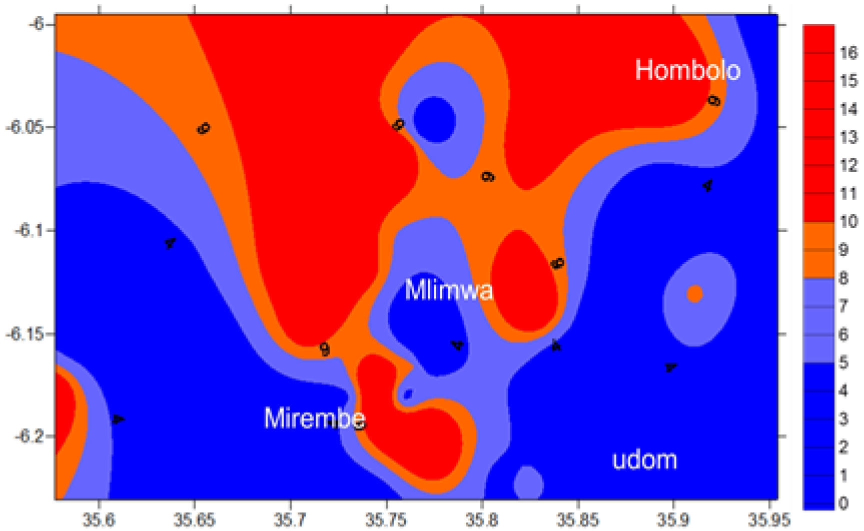

Figure 3.Earthquake amplification map for urban area of Dodoma, based on rating scheme by Noack and Fäh (2001)

IV. SLOPE STABILITY

The stability of slopes is an important factor in the development of Tanzania. Landslides are a significant geological hazard, often are associated with rainfall. The stability of road cuttings and natural slopes has been a major consideration in the extension and maintenance of country's road network. The TANZAM highway has been blocked on numerous occasions by slope failures and several sections have had to be realigned.

In Tanzania, landslides occurs involving thick weathered mantle of residual soil. The main cause of the slides is like to be unconsolidated nature of the soils. Steep topography is also one of the factors contributing to landslide. Westernberg & Christiansson (1999) describe instability on the settlements around Mgeta valley in Uluguru Mountain. This can be considered to be one of the causes of landslides for towns located below mountains such as Morogoro. Landslide problems have a significant effect on the people and infrastructure around the mountain, figure 3 and 4 (Westerberg and Christiansson, 1999; Lundgren, 1978; Lundgren and Rapp, 1974). Problems of instability on volcanic deposits in the northern part of Tanzania have been reported. Triggering of the landslide can be by earthquakes, rainfall and or removal of slope toe due to either excavation or river erosion. One landslide near Makuyuni blocked highway for almost one week, though closure for lesser periods due to slope instability is a common occurrence. This landslide was caused by excessive rainfall which resulted to a continued movements and surge of landslide material. Another landslide occurred recently, April 2013 in the Mushono gravel mine in near Arusha town. This landslide was caused by poor planning of the mine which resulted to the death of 13 people. A major landslide, Same landslide in Pare Mountain occurred in 2009 killing 20 people and destroys homes of 1500 people. A landslide was caused by excessive rainfall on highly weathered and jointed rock mass. Mechanisms responsible for this failure are still unknown, which indicates that there is a need of more studies on the cause of this landslide.

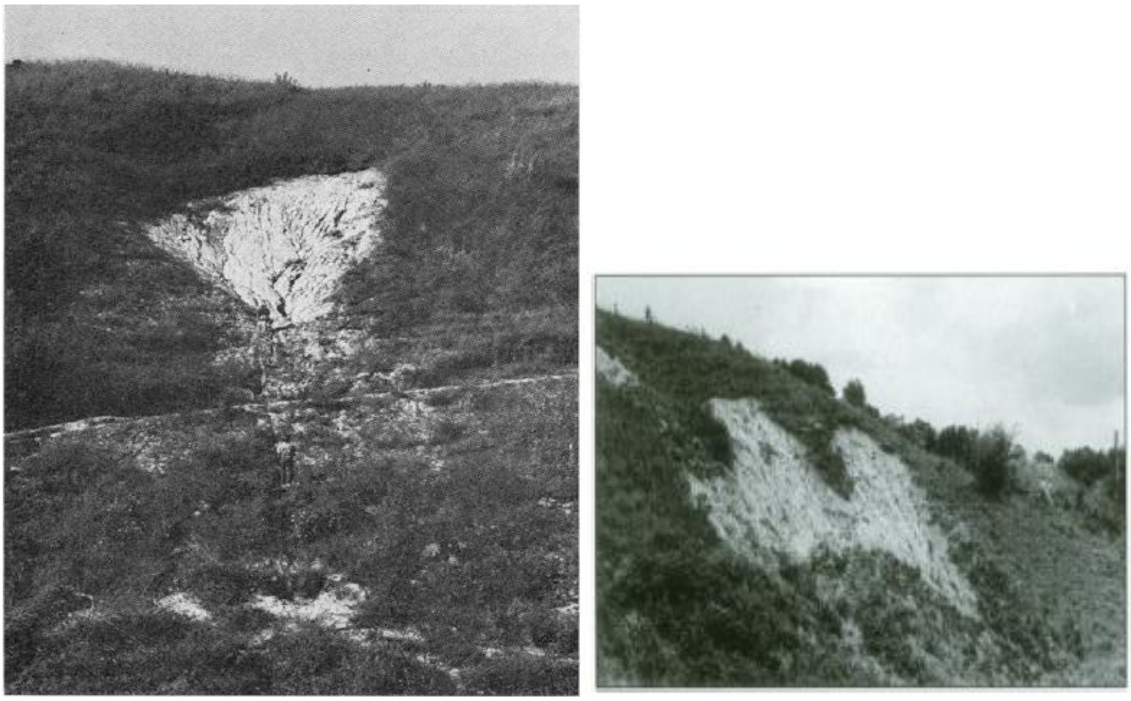

Figure 3.Landslides surfaces around the Uluguru Mountains. This landslide occurred February 1970 (Westerberg, 1996)

Figure 5. Landslide scar near Morogoro town around the Uluguru Mountain (Lundgreen and Rapp, 1974)

V. MINING

The mining industry is extremely important to the economy of Tanzania. It is third largest producer of gold in Africa behind South Africa and Ghana. The majority of the gold mining operations are massive gold although significant alluvial gold have been worked. Major operating mines and projected mining operations are shown in Table 1 and figure 6. Considerable input of engineering geologist has been involved in country two largest open pits operations at Geita gold mine. Engineering geologists have been involved in geotechnical data collections and slope managements.

Geita gold mine is the largest open pit gold mine in Tanzania commenced production of ore in 2000. Currently the mine consists of four open pits namely Geita hill, Matandani, Lone cone and Nyankanga open pit. Of all three pits Nyankanga is the largest pit with slope height between 350 – 400 m. The engineering problems encountered during the development of infrastructure for mine. These include slope stability problems on some sections of the open pits by presence of dipping layers of highly to completely weathered bedrock. The mine slopesare excavated in steeply dipping banded iron formation (BIF). On 3rdFebruary 2007, slope failure occurred in an intermediate footwall Nyankanga pit resulting in failure approximately 200 m high and 270 m wide which can be translated to approximately 7.3 million tons of material accumulated at the pit floor. The cause of the failure was identified to be shallow dipping, north oriented surface in the pit that act as release surface and formed large metastable wedge structure (Dyke, 2009). Despite the magnitude of failure, the Nyankanga pit was safely and effectively evacuated with no injuries to personnel or damage to equipment. This was due to the fact that Geita Gold mine has deployed good slope monitoring systems at its open pit such as slope stability radar, continuous prism monitoring systems and laser scanner system which makes easy to identify different slope failures around the open pit, figure 7. These systems are not interdependent but used as in conjunction with one another to monitor different geotechnical risk to form an integrated risk monitoring system (Dyke, 2009).

Table 2 – Major operating mines in Tanzania

Name	**Method of mining**	**Ore**	**Location**
Bulyanhulu Gold Mine	Underground	Gold	Kahama/Shinyanga
North Mara Gold Mine	Open pit	Gold	Tarime/Mara
Buzwagi	Open pit	Gold	Kahama/Shinyanga
*Tulawaka	Combined underground and open pit	Gold	Biharamulo/Kagera
Geita Gold Mine	Open pit	Gold	Geita/Geita
Golden Pride Gold Mine	Open pit	Gold	Nzega/Tabora
Williamson Diamond Mine	Open pit	Diamond	Mwadui/Shinyanga
Tanzanite one	Underground	Tanzanite	Manyara

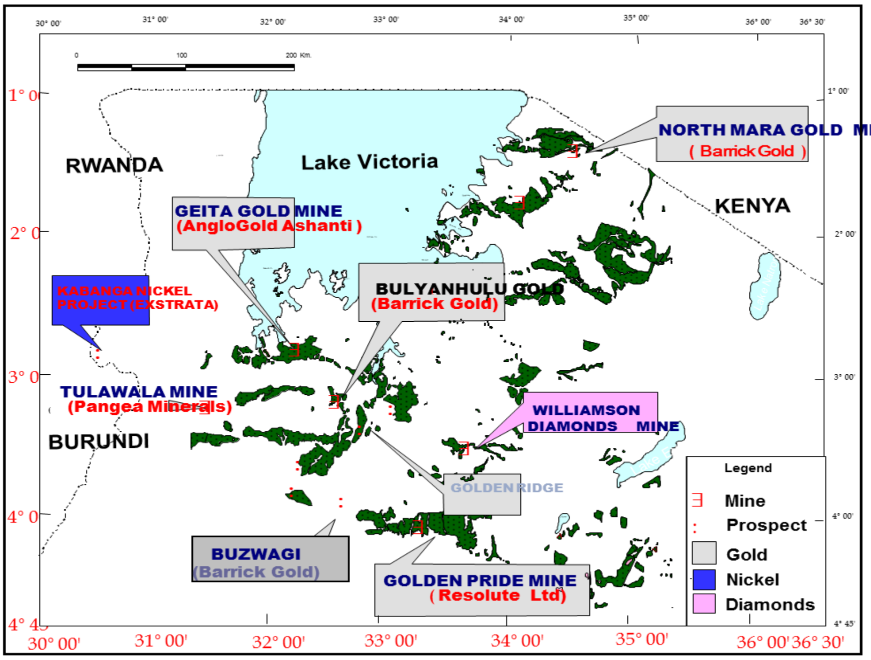

Figure 6.Major operating mines in Tanzania.

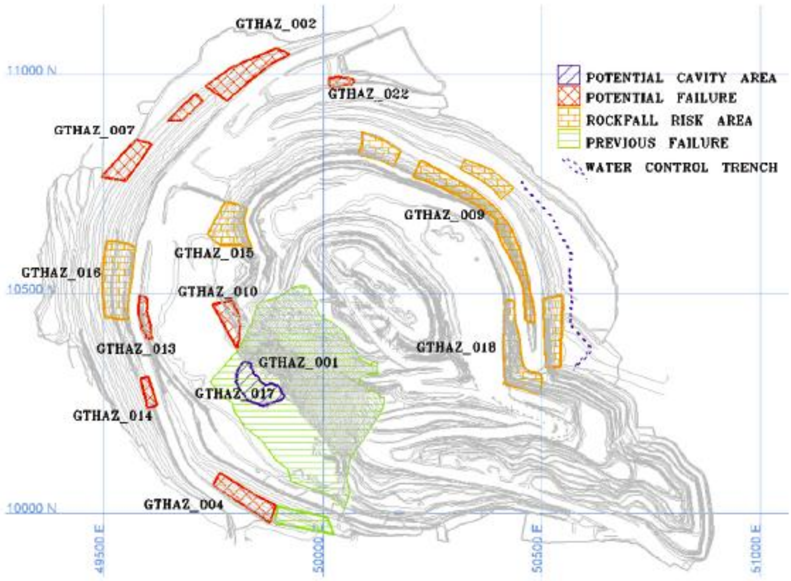

Figure 7. Hazard plan for Nyankanga Open pit – Geita gold mine (after, Dyke, 2009)

VI. URBAN PLANNING

Msindai (2004) carried out an engineering geological mapping for the city of Dar es salaam. This was the beginning of application of engineering geology on the urban planning. In this work, the map was released with supporting information on geomorphological and geological features and provided a terrain database for the expected city expansion and construction. These investigations have enabled a portrayal of the engineering geology of Dar es Salaam region. For construction , Dar es Salaam region have been subdivided into four engineering areas namely; the uplands, the upper coastal terrace , the lower terrace and valley and creeks(figure,8). Very suitable grounds that demands minimal foundation requirement are situated on the upper terrace sandstones and upland sandstones were overburden is >2m and slope angle <5%. Problems related to the development of major urban areas have been subject of several reports (Lupogo et al. 2012; Ferdinand and Nderimo, 2007). The problems which are encountered include rapid weathering of crystalline rocks, expansive clays, limestone dissolution, collapsible soils, dispersive and erodible soils and slope stability. These problems require early identification during the execution of the projects and careful consideration in the engineering design. However, the practice for site investigation in not currently undertaken in civil engineering works. More emphasis on site investigation is required to ensure safer construction in the country. In Dar es Salaam and Coast region engineering problems encountered include the presence of the montmorillonnite rich expansive clays. These can result in heaving of foundations of buildings together with road failures. Lucian (2006) conducted experimental studies on the influence of expansive clays on the cracking of foundations in Kibaha Town. In this research, several methods to reduce the effects of expansive clays in the foundation were suggested. The presence of limestone terrain in the Coast regions has caused a lot of subsidence problems especially in Zanzibar (Gössling, 2001). Very few studies have been conducted on the factors that contribute to subsidence in these regions.

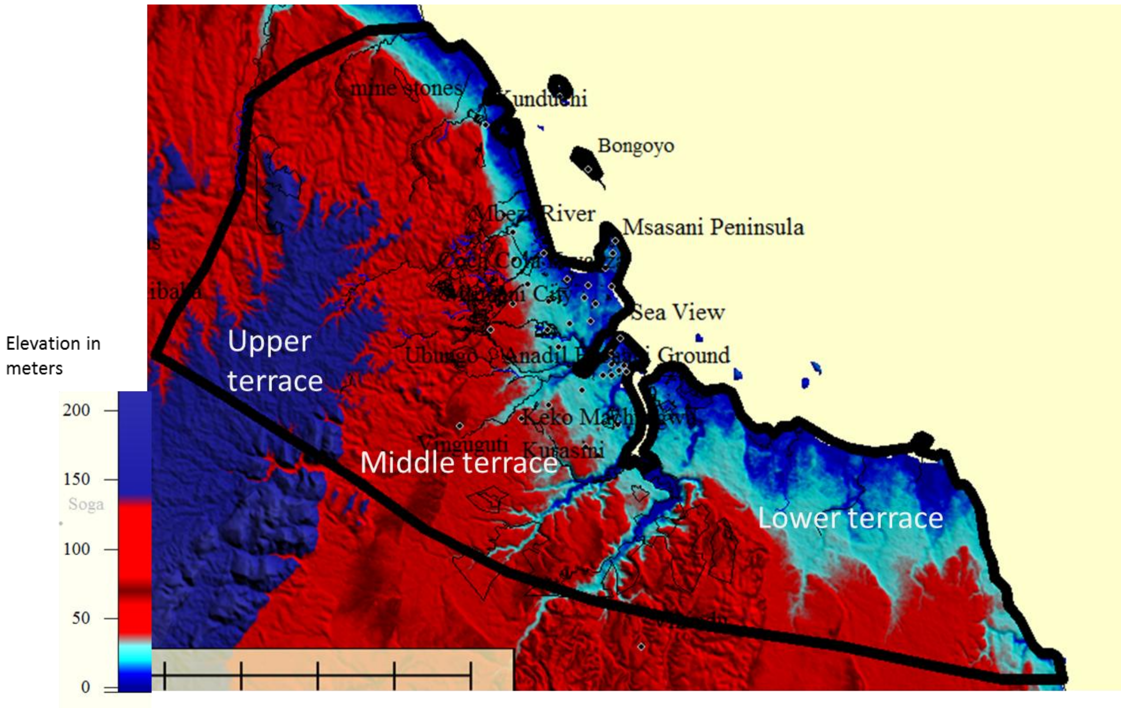

Figure 8 Division of Dar es Salaam based on elevation and engineering geological mapping by Msindai (2004)

Use of unsuitable aggregates for road construction and foundations has been a factor in the failure of pavements countrywide. The importance of locating supplies of suitable aggregate has been recognized for large construction projects and the Engineering Geology Laboratory at University of Dar es Salaam has produced numerous reports on the aggregate potential of selected regions in the country (Lupogo, 2010 ; Lupogo;2011). However, there is a need for these studies to be conducted for small scale projects where large amount of low quality aggregates have been used for constructions.

I. CONCLUSION

The geological history of Tanzania has had a significant impact on various engineering projects such as road construction industry, mining and urban development. The importance of engineering geology in solving these problems and the development of Tanzania cannot be understated. The mineral wealth, the exploitation of hydroelectricity, expansion of cities, successful construction of roads to allow convenient links between urban centers and the monitoring of geological hazards all necessitate considerable input from engineering geologist. The Engineering Geology laboratory of department of Geology - University of Dar es Salaam provides engineering geological and geophysical investigation services and expertise for major and minor projects. The Geological Survey of Tanzania in collaboration with department of geology-University of Dar es Salaam, monitors earthquakes and active volcanos within the country.

The rapid development of Tanzania in recent times where considerable mineral and energy resources must be exploited under frequently highly adverse conditions has resulted in considerable demands being placed on and met by engineers. The geological engineering experience gained will not only be of use to similar under developing countries but also will provide new techniques and design philosophies for use of the engineering profession.

REFERENCES

[1] Dawson, J.B. The Gregory Rift Valley and Neogene-Recent Volcanoes of Northern Tanzania Memoir No 33, 2008 Geological Society.
[2] Hester, B.W. Tanzania – Opportunities for Mineral Resource Development. United Nations Development Programme. Prepared for the Government of Tanzania. Ministry of Water, Energy and Minerals, Dar es Salaam, 1998.108pp.
[3] Daudi, G. "Investigation of the seismo-tectonic structure of the eastern branch of the East African Rift System in Tanzania", Masterthesis. University of Dar es Salaam: Dar es Salaam, 2007.
[4] Msabi, M. "Seismic Source characterization for NTD", MSc thesis. University of Dar es Salaam: Dar es Salaam, 2009.
[5] Msindai, A. Engineering Geological Mapping of Dar es Salaam City, 2004 Tanzania Journal of Science,2004.
[6] Lucian, C .Geotechnical Aspects of Buildings on Expansive Soils inKibaha ,Tanzania. PhD thesis, Stockholm University,2006.
[7] Lupogo, K. Qualitative Microzonation of Earthquake Susceptibility - A case study for Dodoma Urban Area, Central Tanzania. Tanzania Journal of Earth Science, 2013.
[8] Ferdinand, R. and Nderimo, F."Evaluation of Earthquake Resistance of the Arusha international conference Centre", paper presented to the AICC board Arusha, 2007.
[9] Geological Survey of Tanzania. Website,2013
[10] Westerberg, L.-O and Christiansson, C. Highlands in East Africa: unstable slopes, unstable environments? Ambio, 1999, 419–429
[11] Lundgren, L. Studies of soil and vegetation development on fresh landslide scars in the Mgeta Valley, western Uluguru Mountains, Tanzania. Geogr. Ann. Ser. Phys. Geogr., 1978, 91–127.
[12] Lundgren, L. and Rapp, A. A Complex Landslide with Destructive Effects on the Water Supply of Morogoro Town, Tanzania. Geogr. Ann. Ser. Phys. Geogr. 56, 1974, 251–260.
[13] Dyke, G. Best practice and new technology in open pit mining geotechnics: Geita gold mine, Mali–a case study, in: World Gold Conference 2009, The Southern African Institute of Mining and Metallurgy, 2009, pp 169-176.
[14] Gössling, S. The consequences of tourism for sustainable water use on a tropical island: Zanzibar, Tanzania. J. Environ. Manage. 61, 2001, 179–191.
[15] Lupogo, K.. Aggregate quality assesment for Maseyu quarry - Lugoba, Coast region- Technical report,2010 a.
[16] Lupogo, K.. Aggregate quality assesment for Lake Zone quarry - Lugoba, Coast region- Technical report,2011.