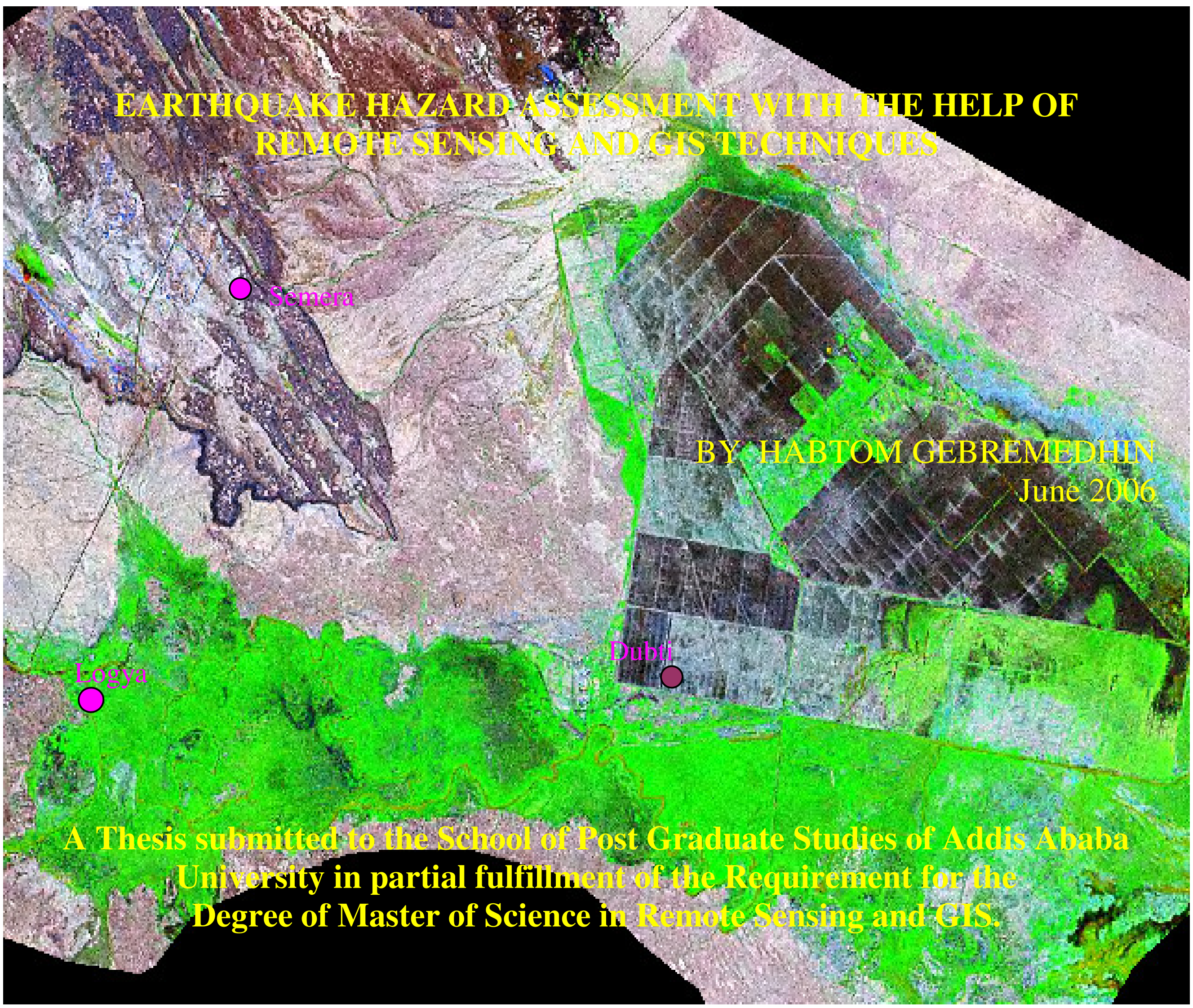
DEPARTMENT OF EARTH SCIENCES
ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

EARTHQUAKE HAZARD ASSESSMENT WITH THE HELP OF REMOTE SENSING AND GIS TECHNIQUES



BY HABTOM GEBREMEDHIN

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APPROVED BY BOARD OF EXAMINERS

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ABSTRACT

The earthquake hazard in an area depends mainly on three factors: - 1) The Regional earthquake sources and seismic wave propagation characteristics, 2) The local geology's response to, and modification of, Earth- quake ground shaking and 3) Type and use of buildings and life lines constructed in the area, which includes the:- the number of people living under the roof, the time the earthquake happened ,night, rush hour, day time etc. In this study the study area is assessed in terms of these controlling factors, it is found to be the most earthquake hazard prone area in terms of earthquake frequency, in terms of population density, though it is not densely populated now(around 7000), the population in Semera town is expected to grow to around 18,000 by the year 2025, and the type of buildings in the area are from single to two storey concrete type of buildings, an earthquake intensity level of VIII and IX are expected in the area, these earthquake intensities have a power that can damage these buildings, the Ethiopian building code standard uses the same building regulations for all towns in the rift(Arbaminch, Ziway, Nazret, Semera, Dessie, michew, Mekelle, Adigrat, etc),hence the building code needs updating, because the intensity levels expected in semera area is higher than the other areas in the rift.

INTRODUCTION

Semera is situated in central Afar region; it is some 70kms from the former regional capital, Asaita mostly by asphalt road, and 580km from Addis Ababa by asphalt.
Semera lies at an altitude of 430 m.a.s.l and it's weather type is arid. The landscape is flat.The mean maximum temperature is 36.2 ^{0}C with a minimum of 19.8^{0}C.Annual rainfall is around 205mm.

The National urban planning Institute (NUPI) Development plan based its population forecast for Semera on 60% of the applicants for plots, plus the movement of the 486 workers in regional bureaus when the capital city of Afar was shifted from Asaita to Semera, The NUPI gives a 1997 population of 3678,growing to 5200 in2002 and 7523 in 2007 based on the report of regional bureaus, there are no meaningful figures of population done by CSA for Semera.

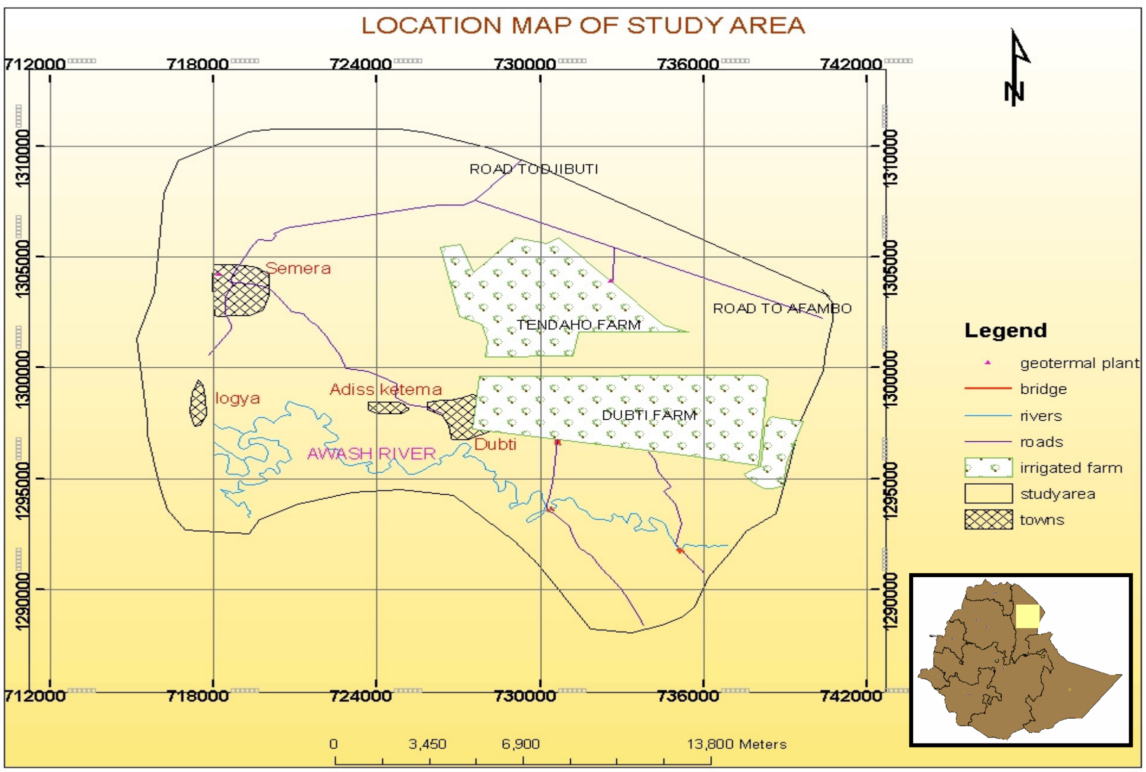


Figure-A Location map of study area

The NUPI forecast the population to grow according to three variants, with annual rates of 5%, 6% and 7%, starting with 3678 in 1997.

Table-1: population forecast-semera

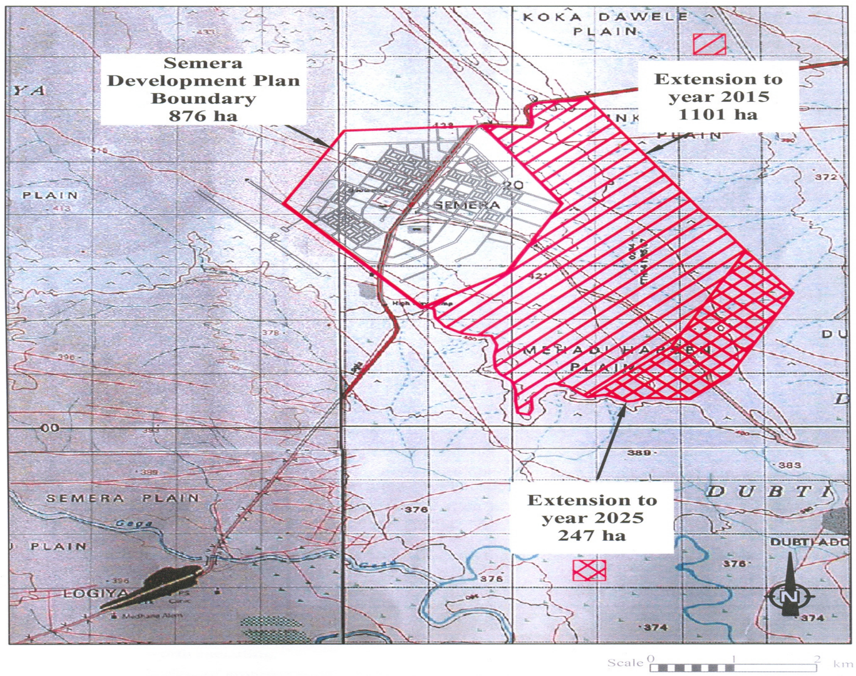
Horizon	2005	2010	2015	2020	2025
Growth rate p.a.to next horizon	4.0%	3.8%	3.6%	3.5%	
Population	8,439	10,267	12,372	14,765	17,537

As the Nile is the life of the northeastern African dessert areas (Sudan and Egypt), The Awash river is the life of the Afar Depression, it makes hundreds of kilometers of meandering course and ends at lake Abe, at the border of Ethiopia and Djibouti, it travels for more than 700kms.

On the northern direction of Semera there is an active volcano-tectonic activity at Erta'ale and Teru Boina localities as it can be shown in the following photograph. Last year it showed an increase in its extent and migration towards Semera town, scientists and researchers studying the situation say that it is a threat to the capital town of Afar, Semera and the road that goes to the port towns of Assab and Djibouti.

The present Development plan for Semera town allows for an area of 8.8km^2 ,which is expected to increase to 22.2 km^2 by the year 2025.Using the CSA urban population growth rate of Afar Region ,the population will grow to 12,371 in the year 2015 and to17,537 in the year 2025.The average growth rate would be 3.7% per annum from 2005 to2025.

Figure-B: Semera development plans boundary and assumed extension areas, taken from reversibility study manual by ministry of water resources



There is no sanitation system yet constructed in Semera, though a sewerage system has been planned, but so far not implemented. by the year 2025,Semera will generate a waste water flow of 1098m^3 per day, or 25 liters per second when factored for peak flow. This is insufficient to warrant the introduction of sewer system and on-site sanitation will therefore be the methods of sewage disposal.

Background and justification

What inspired me to make a research on this topic is, the report by geophysical observatory at Addis Ababa University, that describes the occurrence of a series of seismic and volcanic activity was recorded in Afar from September 10/2005 up to September 28/2005 ,earth quakes occurred as swarm of events with magnitudes greater than 4.3,with the largest events recorded on September 21/2005 with a magnitude of 5.6 and 5.5 Richter scale ,respectively. This was accompanied by fissuring, cracking, collapse of pre- existing fault plane, and fragmentation of rocks, local sliding, normal faulting and volcanic eruption, as a result of these volcano-tectonic and seismic activities large part of the eastern part of the country was threatened. Some domestic animals were killed and injured, local houses destroyed, pre-existing hot springs and artificially dug water wells were collapsed.

The problem has a multidisciplinary nature, Last year from sep. 20/2005 to sep. 27/2005 there were a swarm of earthquakes in a span of eight days, whose epicenters were mostly north of semera, and slowly the epicenters migrated to south, towards semera area. a 60 km long crack and 8m wide onst part was created whose southern tip is about 20 km far from Semera, this can slowly extend to semera as ion figure 1b, or generally towards the road going to the port and the dams on the Awash river.

Figure-C: A crack formed due to volcano-tectonic activity in September 2005 in Teru wereda in Afar, from www.BBC news, new ocean opening.

OBJECTIVE OF THE RESEARCH

General objective

. Here the objective is to assess the hazard in terms of land use for erecting different engineering structures, prepare an important information in a way that decision makers can understand it and use it, to classify the land for erecting different engineering structures, For example, land for building Dams, oil and gas reservoirs, for nuclear plant for waste disposal, land for high storey buildings, for dwelling, etc as part of the LAND INFORMATION SYSTEM (LIS) of the Regional Government that can help decision makers, planners and designers to plan and design engineering structures like buildings,

dams, towers water and oil reservoirs , in a way that lose of life and property due to geo-hazards like ground shaking will be minimized.
-To trace the direction of extension of the 60km long crack during the earthquake swarms in 20-27 September 2005, and to examine its influence on infrastructure like road, Semera town, Dams and irrigated land which are about 25 kms south of the crack.
-to assess the seismic hazards that would affect the area in the future and to collect and present this information in a format that would be useful to:-government agencies, planners, construction industry etc-to quantitatively assess the threat of tectonic and seismic hazard around Semera area in terms of factors like local geology, slope ground water level etc, as it is the capital town of the Afar Regional governmental state and as there are many new projects in the area, and - to prepare a Data Base that can serve as good reference data for further research in the area.
Specific Objectives
• Active fault mapping, buffering analysis
•Epicenter mapping
•Delineating high earth quake intensity areas
•Preparing a data base of cultural activities, construction and investment, infrastructure facilities in the study area.

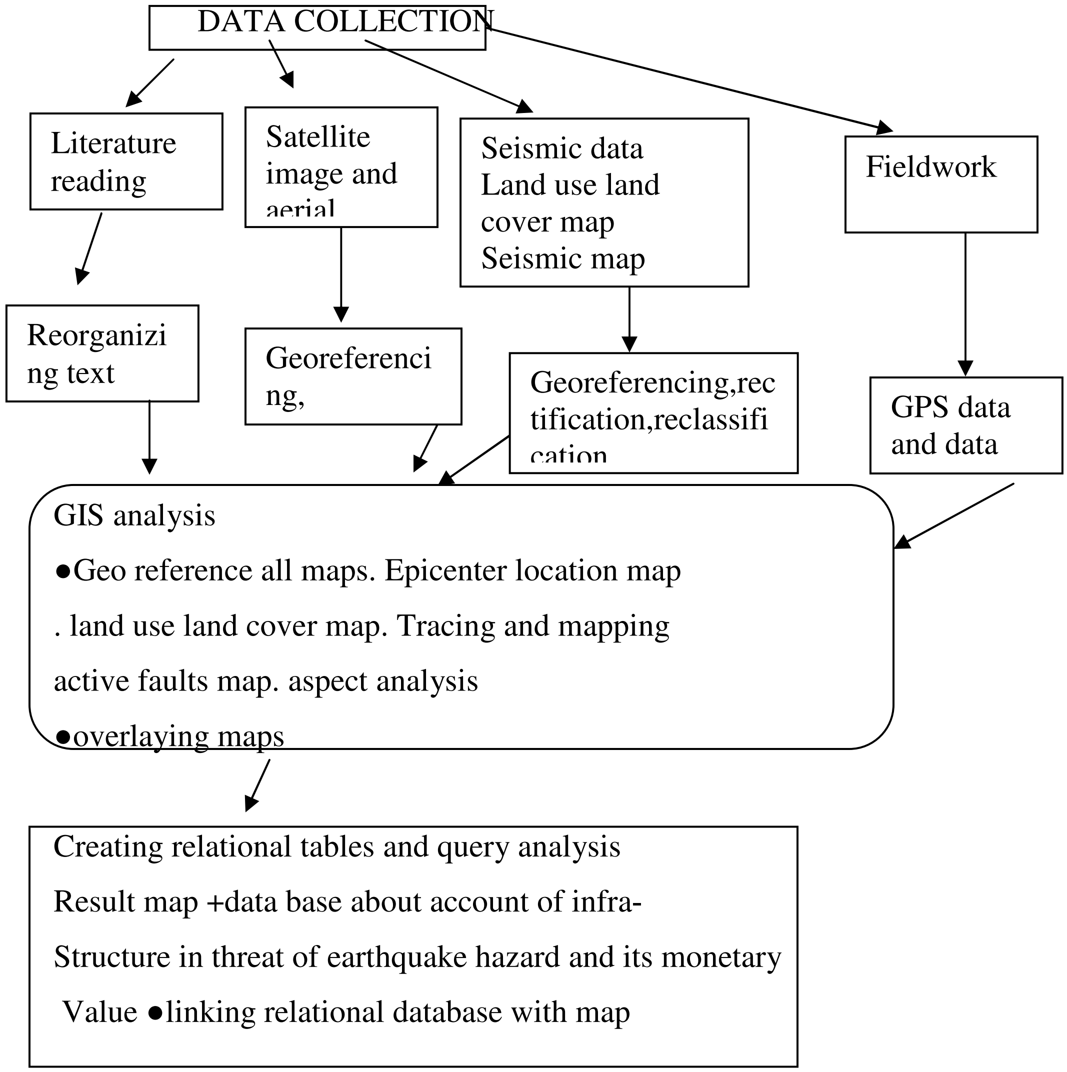
MATERIALS AND METHODOLOGY

Materials and methods used to achieve the above objectives

● Literature survey, discussions with relevant people on review findings,
● Topographic maps, seismic maps, tectonic maps,
● Satellite image land sat geocover2000,14.2 by 14.2 meter resolution and aerial photograph of 15 by 15 meter resolution from NASA.
● Human settlement data,
●Digitizing maps, Editing, Encoding of all attribute data collected,
● geo referencing, geometric and radiometric correction of satellite Images,
● Enhancing and interpreting satellite images using different image Processing techniques (like high- pass filter, low-pass Filter, image subtraction etc),
● Calculation of changes in land form and structure
● Field work (ground truth, and
●GIS analysis (lineament analysis

- Active fault mapping (fault drop)

RESEARCH METHEDOLOGY



CHAPTER-1

Application of Remote Sensing and GIS in geologic Hazard mapping

Remote Sensing and its kindred technologies, such as geographic information systems (GIS) and the global positioning system (GPS), are having a pervasive impact on the conduct of science, government, and business alike.(Lillesand and Kiefer, 2000).

Remote Sensing the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation. It can be thought as the eyes of getting unlimited source of biophysical and socioeconomic data, due to its synoptic visions from an aerial or space vatage point.

It has an amazing application in indirect mapping of a ground covered by dense vegetation and in accessible area, because by remote sensing we can identify vegetation species (0.45-0.67µm,chlorophyll absorption bands) 0.7-1.3µm is used for vegetation discrimination;

With radar images we are able to map buried channels below the surface l-band (23.5-cm) radar waves have penetrated usually far (at least 1 to 2 m) into the ground and reveal the underlying bedrock structure. It is possible to identify previously unknown buried river channels and gravel terraces apparently associated with an ancient drainage system.

As different vegetation species have different spectral reflectance properties, and vegetation anomaly is mainly a function of the variation in soil and rock chemistry .Usually Field spectrometers (for ground based measurement of reflectance and/or emittence of surface materials) are used to collect reference data in accordance with principles of statistical sampling design for a particular application .Hence it is much cost effective than the conventional methods of mapping. This doesn't mean that Remote sensing is as an alternative to field investigation, rather remotely sensed data must be supported by field data, field observation, sampling and subsurface exploration. Its geological application passes through:-

-Defining the problem

-Selecting appropriate resolution (spatial, spectral, radiometric, Temporal)

-Selecting data set (available sensors)

-Data processing

-Interpretation

-Application

The main steps in using Remote Sensing technology are: 1)Acquiring data(data acquisition) and 2)Data analysis and application. Data analysis and interpretation are subjective, it depends on experience, knowledge of the area to be investigated and quality of the data, however, there are some standard image or photo interpretation elements, which are common to different experts; these are:-Shape, size, pattern, tone, texture, shadow, association and site.

1) SHAPE:-we can identify ground objects based on the general form of the objects.

2) SIZE:-relative size of objects is used to compare objects on the ground, example, caldera and crater, joint and/or faults.

3) PATTERN:-refers to spatial arrangement of features, example, drainage patterns.

4) TONE:-relative brightness variation or color of objects in an image.

5) TEXTURE:-frequency of tonal variation, e.g smooth texture like that of grass land.

6) SHADOW:-dark zone due to illumination direction, it shows look direction.

7) SITE:-refers to geographic location and topographic conditions of the area, latitude and Longitude, and hence we can identify lowland or highland and specific type of Vegetation, e.g acacia grows in low lands of tropical region.

8)ASSOCIATION:-is the occurrence of certain features in relation to others. e.g flamingo birds are found with saline lakes, there is a special type of grass growing In oil seepage areas, violet flowers growing in copper bearing rock et.c

1.1. Geological features that can be identified from remote sensed data (images)

-Regional geology in reconnaissance survey (sedimentary, metamorphic or Igneous)

-Metamorphic belts, shear zone, ophiolite zones

- Site of reserves minteral guides (alteration zone, rock associations, structures and lineaments.

- Oxidation products, morphology (big folds, faults), drainage patterns, vegetation Anomaly.

-Buried channels, deltas, abandoned meanders, old beaches and lagoons, scrolls, calderas,

-Structural changes in plant morphology (vegetation density, change in leaf shape, in flowers, fruits, change in leaf color, dwarf ness), example, dwarf ness shows presence of acidic soil, abnormal branches and leaves shows presence of radioactive elements in granite area e.g. Diredawa area in Ethiopia.

-in ground water exploration, to identify soil moisture and aquifers, springs, recharge zones, rivers, canals, lakes, ponds, high drainage density shows low ground water potential.

1.2. Uses of geographic information systems (GIS) in

Geology and, in seismic risk assessment.

The most important applications of GIS in geology involve three stages, applied to data planes in raster format. First is the breaking up of perceptually complex data planes into simpler and more-interpretable forms related to geological features (breaking complex tabular data in to related series of tables with capability of querying, modifying, updating the data called relational database (to create geo- database) using programs, access and

SQL). An example is analyzing remotely sensed planes to extract drainage and topographic patterns, curvilinear features and stands of litho logically related vegetation. Another is outlining geochemical and geophysical anomalies, which might represent deeply buried intrusions or major faults. Secondly, different data planes can be combined to form a more coherent and geologically significant whole. Such a synthesis allows possibly significant correlations to be discovered and analyzed. The third is theoretical interpretation of results of data plane analysis and synthesis in terms of various geological models, or the development of new models specific to a particular area At any stage result can be expressed as simplified maps, which can be added to a vector- or grid-format, GIS to aid in decision-making. Example identifying sites that are prone to rapid erosion, combining vector-format data plane of land ownership to the results of a reconnaissance aimed at generating targets for mineral exploration. Some GIS analysis can be applied like density slicing and introducing color to each slice to increase its interpretability.

Chapter-2

Earthquake hazard history around the study area

Due to its harsh climate (hot temperature up to 36 ^{0}Cand scarcity of surface and/or subsurface water) the area is sparsely populated, there is mostly nomadic life style and life is mostly based around the awash river and its tributaries, due to these reasons there have not been crowded towns with modern buildings, therefore high intensity earthquakes that occurred at the area in the past do not cause much casualties, compared to similar events in other parts of the world. People living in the area witnessed that they had felt ground shaking many times in their lives, two towns, which are close to the study area, Serdo and Majeti were heavily damaged.

Table2.1historical records of damaging earthquakes in Ethiopia

Year	Epicentre Dist from psa	Magnitude	
1906 MER earthquake		$M_{p=6.8}$	Was potentially damaging earthquake
1961 kara korie e. quake		MS=6.6	The town of Majeti in the epicenter area was completely destroyed
1969 centeral Afar		Mp=6.3	Destroyed the town of serdo in epicentral areas
1983 Wondogenet		Mb=5.1	Caused some damage in the MER.
1985 Langano		Mb=4.6	,, ,, ,, ,,
1987 southern most of MER		Ms=6.2	Was widely felt causing a wide spread damage
1989 sequence of e.quakes in Dobi graben		Ms=6.3	Several bridges on the highway connecting the port of Assab to Addis Ababa were

			destroyed.
1990 Juba		Ms=7.1	Was widely felt in southern Ethiopia
1993 Nazret			Caused damages to property
1995 Awassa			,, ,, ,,
20-27Sep.2005 earthquake sequence Erta'ale and 200km south of it.		4.5 5.4 5.0 4.6 5.0 4.7 4.9 5.6 5.1 5.0 4.6 4.7 4.8 4.8 4.4 4.8 4.8 4.6 5.0 4.5 5.5	Followed by new enhanced eruptions from Ert'ale volcano Hot springs disappeared and replaced by smokes, accompanied by cracking and fissuring, some local houses and water wells were destroyed,200 goats and59 camels engulfed a women injured.

What we can infer from these recent historical records is that the rift area is characterized by damaging earthquakes. These earthquakes are due to tectonic activity, hence a detailed study of fault patterns and characteristics like fault geometry at depth using geophysical and geological approaches is necessary.

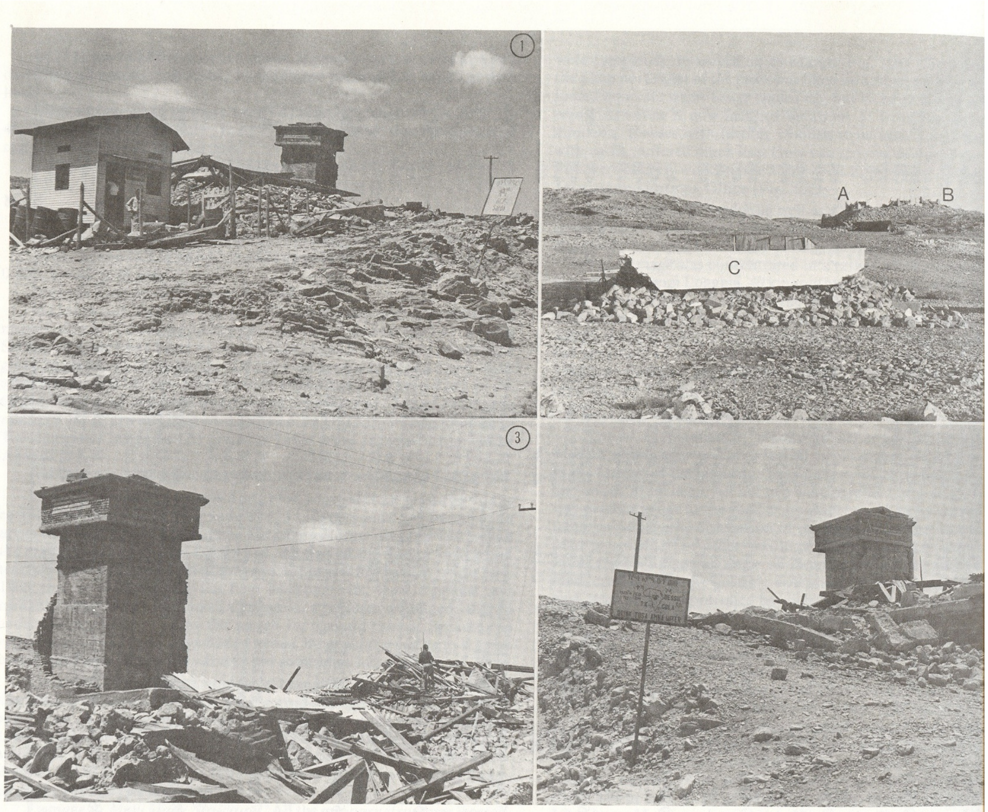


Figure 2.1 ruins of Serdo after the main shock of 29 march 1969,nothing was left intact except the wooden shack of the telecommunications board (upper left, plate and the wooden house north of the town, in Afar, Serdo the light structures stood the shocks. On the upper right of plate 2,the silhouette of the section of the village erected on the Serdo ridge can be seen. The letter A locates the highway authority compound. B the reinforced concrete water tower leaning about 5^0 SW, and C the village school that had housed 30-35 students 2 h earlier. Plates 3 and 4 show the water tower, deprived of its brick facing, but still standing among the ruins of the post office and Police head quarters. From Pierr Guan 1978.

CHAPTER-3

Factors that contribute to earthquake hazard in general:-

3.1 Regional earthquake sources and seismic wave propagation characteristics

When we talk about nature of earthquake sources and propagation characteristics, we mainly refer to the destructive energy of the waves, which is determined by the magnitude in Richter scale and the acceleration of shaking the ground; the epicentral distance of the earthquake event has also affects because, the destructive energy of the earthquake decreases with distance, hence an earthquake ruptured at distant point from a building but with higher energy may have the same effect as another earthquake which took place near the building but with lower magnitude, mostly earthquakes of magnitude above 4 are the once that affect engineering structures.

3.2 The local geology's response to, and modification of,

Earth- quake ground shaking

Once the seismic waves arrive at a given location, the local geology has great potential to modify the shaking and/or to modify to the shaking in such a way as to increase the potential for damage and injury. The topography of the ground surface or of buried bedrock may amplify and focus the shaking. The soils (unconsolidated earth material, not bedrock) may also amplify the shaking. Saturated granular (non clay) soils may liquefy and lose their strength, resulting in ground failure or foundation failure. Landslides or slop failures of various types may be triggered by the shaking. The type and distribution of different rock and soil types together with some information on their material property (like:-grading/sorting, mineralogy) is needed to assess the hazards. A standard geologic map is a commonly available starting point. Data on the material properties of geologic materials may be available from previous studies such foundation investigations.

The effect that all the above has on a building or lifeline facility is a function of its design and construction. The injuries and economic impact are dependent on the use and occupancy of the building or facility.

The tool for assessing the hazard and risk for this component is an inventory of the buildings and lifelines in an area, which should include the geographic locations and as much detail as possible on the design, construction, use and occupancy. Tax records and building permits are two commonly available sources for this type of information.

Knowledge and interpretation of the local and regional geology is essential for understanding. The most severe damage. The most sever damage done by an earthquake is commonly concentrated within limited areas, the damage in these areas is caused by one of the following phenomena.

• Amplification of ground shaking by a “soft” soil column.
• Liquefaction of water-saturated sand, creating “quicksand areas”.
• Landslide triggered by earthquake induced shaking.

Potential effects at allocation (Bolt,1993) can be evaluated before an earthquake if good data are available on the thickness and nature of geologic materials (rock and soils).The results of these locally generated phenomena may range from people walking from their sleep to buildings collapsing or gas lines rupturing, depending on the size and location of the earthquake which causes the shaking. Holzer (1994) showed that 70% of the damage during the Loma Prieta earthquake was associated with amplification of ground shaking. 1.5% was due to liquefaction, 0.5% was due to land slides, while ground rupture or tsunami caused no damage. Only 28% was due to “normal” ground shaking. The liquefaction and landslide numbers are relatively small because these phenomena can only occur in very restricted(and map able) parts of the area affected by the earthquake.

The simplest earthquake hazard map is a standard geologic map, by showing the distribution of hard versus soft rock versus soils, a geologic map delimits the areas where the damage increasing modifications and responses to earthquake shaking are more or likely.The general rule is that sites underlain by softer material will be more affected than the hard rock sites From the starting point of geologic map, more and more refined interpretations of hazard are possible. Information on the material properties of the soil and rocks below the ground surface is also useful. The more that is known about the nature and distribution of rock and soils, the more detailed is the analysis and assessment of the earthquake hazard that can be done.

The detail of mapping depends on the fiscal and personnel; resources available and the value of existing or expected development or redevelopment.

3.3Type and use of buildings and life lines constructed in the area

Damage and loss of life can be sustain ably reduced by sitting structures on solid bedrock or dense soils and by building structures that adhere to strict seismic building codes. Buildings that are constructed of strong, flexible, and light materials such as steel, wood, and reinforced concrete(strengthened by steel rebar) are the most resistant to damage by seismic shaking. Houses built with unreinforced concrete block or brick, which are only as strong as the mortar holding the blocks and bricks together, tend to lack flexibility and crumble in large earthquakes.

Being prepared for an earthquake can reduce the damage to property and chance of serious injury or loss of life. There is a saying, “earthquakes do not kill people, buildings do.” Therefore we should do the following:

1) Make sure that your house is firmly attached to the foundation with anchor bolts. Repair any deep cracks in foundation or ceiling, brick chimneys should be braced and anchored to the roof joists.

2) Check for hazards inside the home, tall bookshelves should be bolted to the wall, place heavy objects on the bottom shelves, flammable items and household chemicals should also be on the bottom, heavy pictures and mirrors shouldn't be hung, where people sit or sleep.
3) Learn how to turn of all utilities at your house like gas utilities during an earthquake to avoid fire.
4) During an earthquake, if you are indoors, drop, cover, and hold under a heavy piece of furniture positioned against an inside wall, or crouch in a room corner, stay away from windows or anything that can fall on you. Most injuries result from people leaving the buildings and being hit by falling debries or downed utility lines in unreinforced buildings. From the above discussions we can say that an area will be prone to earthquake hazard only if there are people living there or infrastructure that can be destroyed, other wise ,if it is bare land it will not have hazardous effects.

Earthquake is one part of the environmental systems, it induces landslide and ground cracking this facilitates weathering and Eros ional processes.

CHAPTER-4

Regional earthquake sources and seismic wave propagation characteristics.

A probabilistic Seismic hazard analysis was carried out to obtain hazard maps for Ethiopia(Fekadu Kebede and Laike Mariam Asfaw Addia Ababa university) .The hazard maps were produced for 0.01,0.005 and 0.0033 annual probabilities of exceedence. The seism city data were checked for completeness with respect to time and magnitude, B-value was obtained using maximum likelihood method and seismic source zones were identified on the basis of seismisity and tectonics.

High horizontal peak ground acceleration(PGA) of 0.14g,0.19g and 0.22g for 0.01,0.005 and 0.0033 annual probabilities of exceedence, respectively, were obtained for both the Afar and southern Red sea; relatively low horizontal PGA values of 0.1g,0.13g and 0.16g for 0.01,0.005 and 0.0033 annual probabilities of exceedence, respectively, were found for the Main Ethiopian Rift.

Using extreme value method, Gumbel type intensity(I) values ranging from VIII-X,IX-XI and X-XI for the 100,200 and 300 years period. Even though the seismic activity for afar is higher than that of MER and the Southern Most Rift of Ethiopia, intensity results obtained with the extreme value method for the two regions were similar.

4.1 MODEL INPUT PARAMETERS

A catalogue of earthquakes consisting of location, time of occurrence and magnitude is a fundamental input in seismic hazard assessments. The three-time period for the earthquake catalogue: historical(pre-1900),early instrumental(1900-1963) and modern instrumental(since1964) have been the subject of intense research by Gouin (Gouin 1979).Gouin used Seismological data recorded by stations out of Ethiopia(Europe and Middle East) as, there were no stations in Ethiopia Until the end of Second world war.

Seismisity

Intermediate size($5.5<M<6.5$)earthquakes were recorded from Afar, for example: Serdo(central Afar) in 1969,M_s=6.3,Dobi graben 1989, M_s=6.3,Karakore 1961,with M_s=6.6

To characterize the seismcity, which is a fundamental input in the analysis of hazard, the Gutenberg and Richter relation (Gutenberg and Richter,1954) expressed in the form:

$$\text{Log } N(m) = a - b\, m$$

Is used, where N(m) is a cumulative number of earthquakes with magnitude greater or equal to m. The slop b in equation (1) characterize the seismicity and gives the relative abundance of small and large earthquakes for a given region.

To evaluate b-values, the magnitudes available for each earthquake were first examined, if there is no surface wave magnitude, M_s ,available for a particular earthquake, then the available magnitude is converted to surface wave magnitude, using one of the following relations which have been obtained in the study(By Fekadu kebede ang Laike Mariam Asfaw 1996).

$$M_{BS}=-1.08+1.16m_b$$
$$M_{LS}=-1.03+0.64M_L$$
$$M_{PS}=2.27+.64M_P$$

Where, M_{BS}=surface wave magnitude obtained from body wave Magnitude (m_b)

M_{LS}=surface wave magnitude obtained from local magnitude(M_L),

M_{PS}= ,, ,, ,, ,, personal judgment (M_P),estimated,

Once all the magnitudes are converted to to surface wave magnitudes, the largest of the converted value is used in the evaluation of b-value.The b-value itself is computed using the maximum likelihood method(Weichert,1980),According to the study made by Fekadu Kebede andLaike Mariam Asfaw and others and recent developments in tectonics identified the eight earthquake source zones for Ethiopia as the main contributors of damaging earthquakes, each seismic source zone is defined by some homogeneity in its observed seismicity(earthquake epicenters) and tectonic characteristics, the main tectonic features for my study area are: the western margin of the Afar depression(Srismic Zone-3) and the Afar depression including Djibouti area(seismic zone-4).The main seismotectonic features for these zones are:

Zone-3, western margin of the Afar depression, surface geology and focal mechanisms of recent earthquakes show that this rift margin is dominated by normal faulting (Shudofsky,1985,Fekadu Kebede and kulhanek,1991).Wave form modeling of two earthquakes gives the focal depth to be in the range 14-19 km. Damaging earthquakes have occurred in this region since instrumental recording started in Ethiopia, for example , in 1961 in Karakore a sequence of earthquakes with the largest being, MP=6.6,furthermore this zone is characterized by marginal grabens which are the sites of active continental fracturing, some of the largest earthquakes in this region occurred in these grabens,as an example, KaraKore earthquake, which destroyed the town of Majeti,and caused many damage to karakore by boulders rolled down to the village from the mountains on the left and right side of the village.

Zone-4 covers the central part of the Afar depression and the Djibouti area, seismic activity in this region is usually in the form of intermediate-size and small earthquakes. Examples of damaging earthquakes that occurred in these region are MS=6.3 in 1969 and MS=6.3 in 1989), focal depth obtained from wave form is in the range 5-8 km (see Fekadu Kebede and Kulhanek,1991),Many researchers who studied the Afar depression like(Mckkenzie et al.,1970;Courtillot et al.;19991).As a result of these works a number of models have been proposed and all the models indicate that the region is undergoing overall extension.

As outlined above knowledge of the tectonics of these zones forms the basis for characterizing the real extent of and configuration of source zones for seismic hazard assessment purposes. The following parameters have been used in the identification of source zones:-

1) Earthquake epicenters
2) Major faults
3) Quaternary volcanism
4) b-value(Fekadu Kebede and Kulhanek,1994)

Table4.1 Parameters used for seismic source zoning,M_0 and M_1 denote the lower and upper threshold magnitudes.

Seismic source zone	M_0	M_1	b-value	Rate/Yr
3	4.0	6.7	0.75	1.30
4	4.0	6.4	0.71	2.50

4.2.1 METHODES OF ANALYSIS

There are two methods of analysis for the assessment of seismic hazard at any given site,which are the probabilistic and the deterministic approaches(see Reiter,1990).

Problemastic method :-seismic hazard is defined as the probability of certain level of ground motion being exceeded at given place and with in a given time period. The main input is b-value, activity rate. This is the most widely used probabilistic approach is that of Cornel (1968) and McGuire (! 976,1993), using total probability theorem, the probability of a given ground motion a(acceleration) being exceeded at a given site is expressed in the form:

$$p(A>a) = \iint P(A>a \mid m,r) f_M(m) f_R(r \mid m)\, dm\, dr$$

where p(A>a) =the probability that a given acceleration will be exceeded.
P(A>alm,r) = conditional probability, m= a random variable
f_M(m)=independent probability distribution of m
f_R(rlm=probability density of r for given m.

$$P(I > i \mid m,r) = 1- \frac{1}{\sigma\sqrt{2\pi}} \int EXP\left(\frac{-(i-\mu)^2}{2\sigma^2}\right) di$$

$$K=\left[1-EXP(-\beta(m_1-m_0))\right]^{-1}$$

$$\beta = b(\ln 10)$$

$$f_m(m) = k\beta EXP(-\beta(m - m_0))$$

$$f_R(r|m) = \frac{2r}{I\sqrt{r^2 - d^2}}$$

While,deterministic approach requires inputs of discrete, single-valued events(maximum earthquakes) and models to arrive at a description of earthquake hazard, input parameters are seismic sources(source parameters), size of damaging earthquake(controlling earthquake) and an earthquake ground motion attenuation relationship

$P(I_{max} < i) = Exp(-\alpha Exp(-\beta i)$.

Where $P(I_{max} < i)$= the probability of non- exceedence, alpha and beta are constants

I= intensity

4.3.2 Results:

Using the foregoing methods, hazard maps for Ethiopia for annual probabilities of exceedence of 0.01,0.005 and 0.0033 are produced (using the first approach).Figure 8,9 and 10 show the hazard maps for the 0.01,0.005 and 0.0033 annual probabilities of exceedence, respectively, as obtained from the first approach; while figures 11,12 and 13 show the corresponding intensity maps as obtained from the second approach(extreme value method, Gumbel type I).In the figures, the contoured horizontal peak ground accelerations and intensities are computed at 0.5degrees interval both in latitude and longitude.

Figure 8-10 show that high horizontal peak ground acceleration (PGA) values (0.14g,0.19g and 0.22g for 0.01, 0.005 and 0.0033 annual probabilities of exceedence, respectively) are obtained for Afar depression and southern red sea, similar PGA values are obtained for the region in southern Sudan. The corresponding intensity results are displayed in fig.11-13.for Afar and southern red Sea, they show modified Mercalli intensity values of the order of VIII-X, IX-XI and X-XI for return periods of 100, 200 and 300 years, respectively. On the other hand, in spite of the occurrence of large (MS=7.1) earthquake in southern Sudan relatively (relatively to that of Afar and the southern Red Sea) low intensity levels (VI,VII and VIII. The horizontal PGA values obtained for the main Ethiopian rift and the southern most rifts of Ethiopia are 0.1g, 0.13g and 0.16g for 0.01,0.005 and 0.0033 annual probabilities of exceedence, respectively results are VIII-IX,IX-X and X-XI for 100,200 and 300 years return periods, respectively.

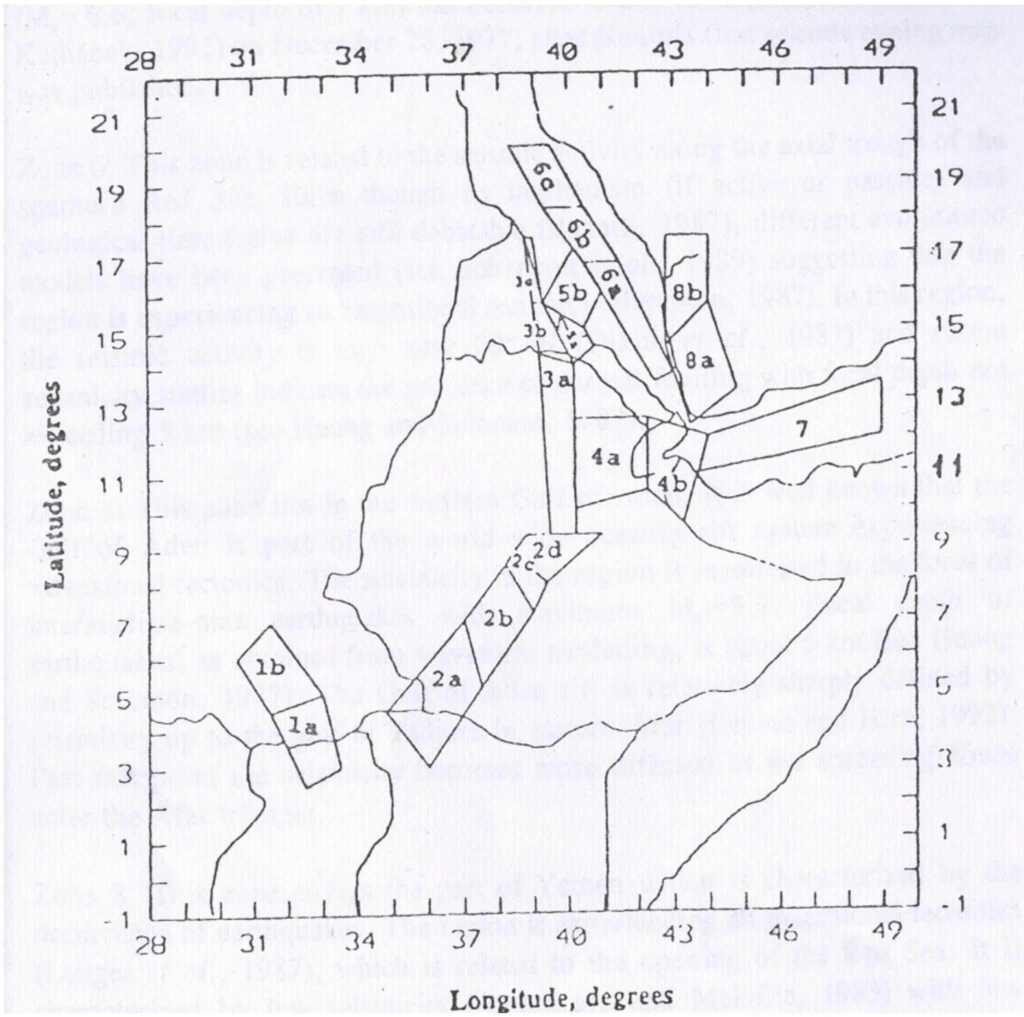


Figure 4.1seismotectonic source zones contributing to hazard evaluation in Ethiopia and the neighboring countries. Numbers 18 in the figure show seismic source zones while alphabets (a,b,etc.) are intended to indicate sub sources within each gross source.

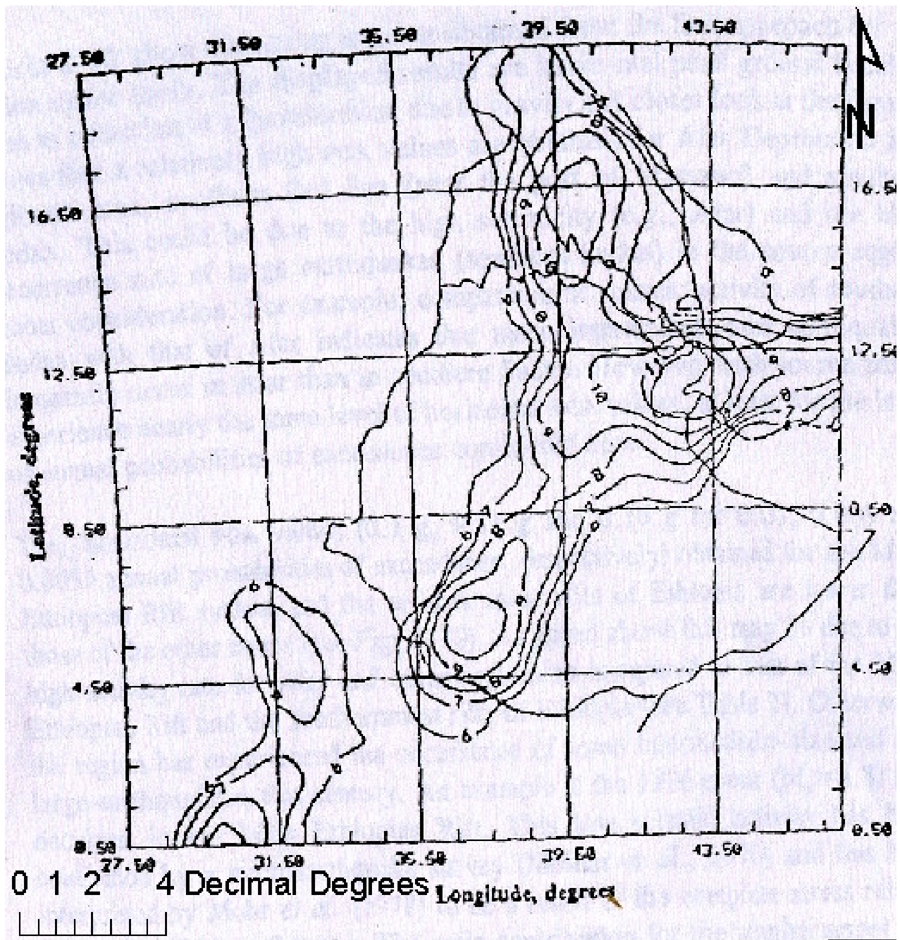


Figure 4.2 Seismic hazard intensity map of Ethiopia and the neighboring countries. The hazard is for 100 years return period with 90% probability of not being exceeded. Contours indicate different Modified Mercalli Intensity levels.

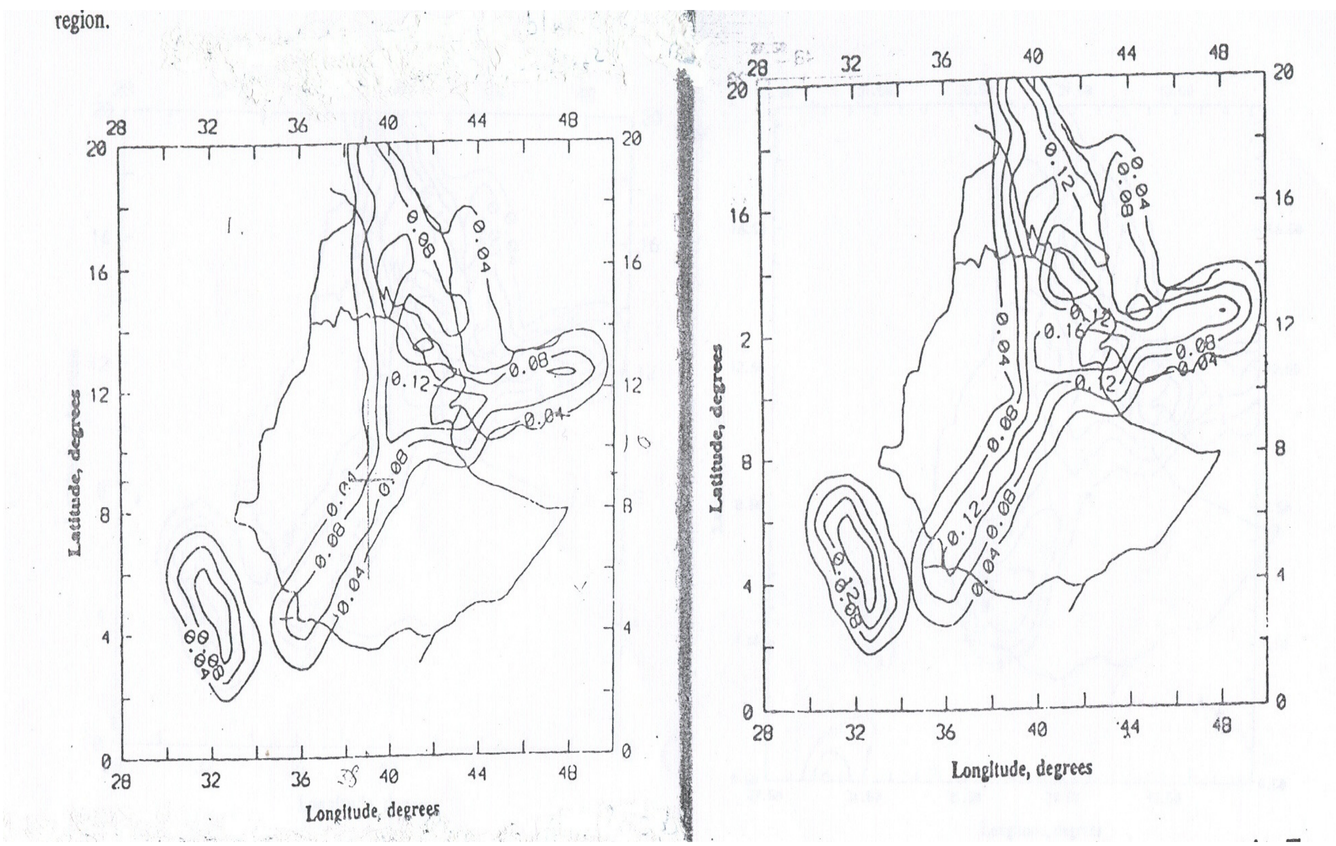


Figure4.3The map on the left shows seismic hazard map of Ethiopia and the neighboring countries. The hazard is for annual probability of exceedence of 0.01.The map on the right shows similar map but for annual probability of 0.005.

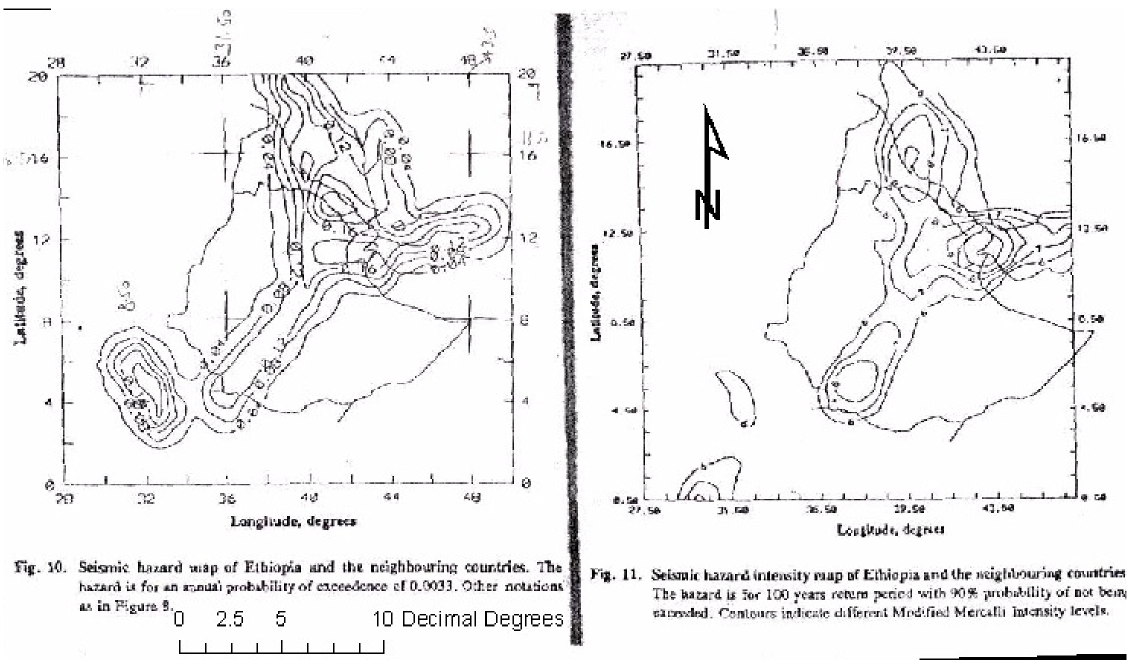


Figure4.4on the left is Seismic hazard map of Ethiopia and neighbouring countries for annual probabilities of exceedence of 0.0033; the map on the left shows seismic hazard intensity map for100 years return period in mercalli intensity scale.

As can be observed in figure-11, the Mercalli's modified intensity scale of earthquake for my study areas is VIII and IX. Intensity VIII means, damage is slight in specially designed structures, considerable in ordinary buildings, great in poorly built structures and heavy furniture is overturned. Intensity IX is defined as, an earthquake in which damage is considerable in specially designed structures, buildings shift from their foundations and partly collapse and underground pipes are broken.

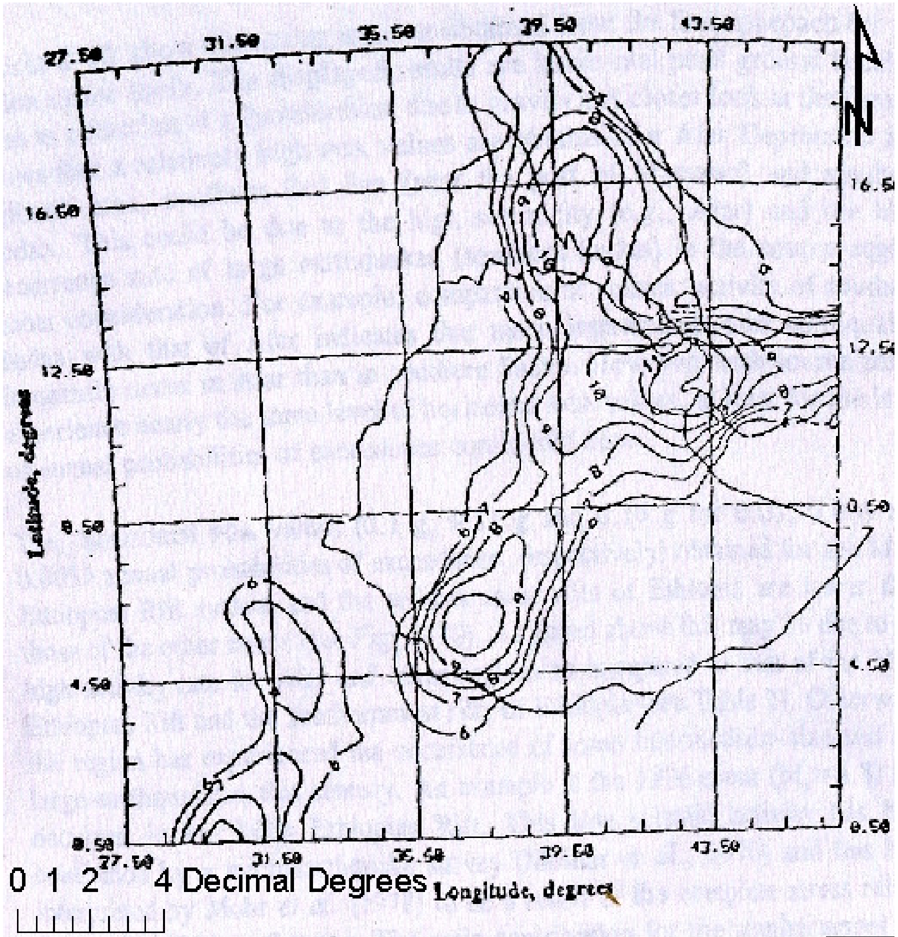


Figure 4.5 Seismic hazard intensity map of Ethiopia and the neighboring countries. The hazard is for 100 years return period with 90% probability of not being exceeded. Contours indicate different Modified Mercalli Intensity levels

The intensity (destructive power) of an earthquake at specific location depends on a number of factors. Foremost among these are (1) the total amount of energy released from this we can assess thestructures and buildings in Semera town, how they are planned, we can classify the area for engineering land use purposes. Figures 8-10 show that high horizontal peak ground acceleration (PGA) values (0.14g, 0.19g and 0.22g for 0.01,0.005 and 0.0033 annual probabilities of exceedence, respectively) are obtained for Afar depression and southern Red sea. Similar PGA values are also obtained for the region in Southern Sudan. The corresponding intensity results are displayed in Figures 11-13 For Afar and southern Red sea, they show modified Mercalli intensity values of the order of VIII-X, IX-XI, X-XI for return periods of 100, 200 and 300 years, respectively.

On the other hand, in spite of the occurrence of a large (MS=7.1) earthquake in southern Sudan relative to that of Afar and Southern Red Sea, low intensity values (VI, VII and VIII for 100,200 and 300 years return period, respectively) are obtained fro this region.

4.3.3 DISCUSSION AND RESULTS OF THE FIRST FACTOR

Figure 8-10 show the zoning maps as obtained from the first approach for the region under study. The displayed results are horizontal peak ground acceleration as a fraction of g(acceleration due to gravity).A closer look at the figures show that a relatively high PGA values are obtained for Afar depression and Djibouti area Southern Red Sea and southern Sudan. This could be due to the high seism city (e.g. Afar) and the high occurrence rate of large earthquakes (southern Sudan) in the source region under consideration. For example, comparison of seismic activity of southern Sudan with that of Afar indicates that more intermediate-size earthquakes frequently occur in Afar than in southern Sudan, however both source zones experience nearly the same level of horizontal PGA values, at least for the level of annual probabilities of exceedence considered here.

The horizontal PGA values(0.1g,0.13g and 0.16g for 0.01, 0.005 and 0.0033 annual probabilities of exceedence) obtained for the main Ethiopian Rift system and the Southern most rifts of Ethiopia are lower than those of other zones; as stated above this may be due to the high activity rate for Afar and other regions as compared to that of the main Ethiopian Rift and the Southern most rifts of Ethiopia.

The horizontal PGA values for the western margin of the Afar depression (one of the seismically active areas in the region), around 10.5,^{0}N and 40.0 ^{0}E and 0.13 g,0.16g and 0.19g for 0.01,0.005 and 0.0033 annual probabilities of exceedence, therefore, this region can be classified as one of the most important regions with respect to seismic hazard.

In general, fig.s 8-13 show that there is an overall good correlation or similarity between the first and the second approaches. Further more, intensity results are converted to peak horizontal ground acceleration using the relation given by Trifunac and Brady (1975).This is expressed in the form:

$$\text{Log } a = 0.30I+0.014$$

Where I=modified Mercalli Intensity and a= horizontal peak acceleration in cm s^{-2}.

-VIII .A.3 Seismcity Report H9803, Revision 1

According to the results set by a study (Aquater1995 i), seismic energy in the Tendaho Graben is not released in the shallow layer of the crust, as proven by the micro seismic survey carried out by Aquater from 1989 to 1994,which pointed out the prevalent distribution of the foci with a depth ranging between 5 and 10 km, the maximum magnitude is less than 3 the majority of events was recorded 15km from the Dubti geothermal area towards the NW and in different structural context. But Events ruptured out of study area also affect or can bring hazard depending on the energy released (magnitude), hence it needs to set up a network of seismometers to monitor the entire surrounding.

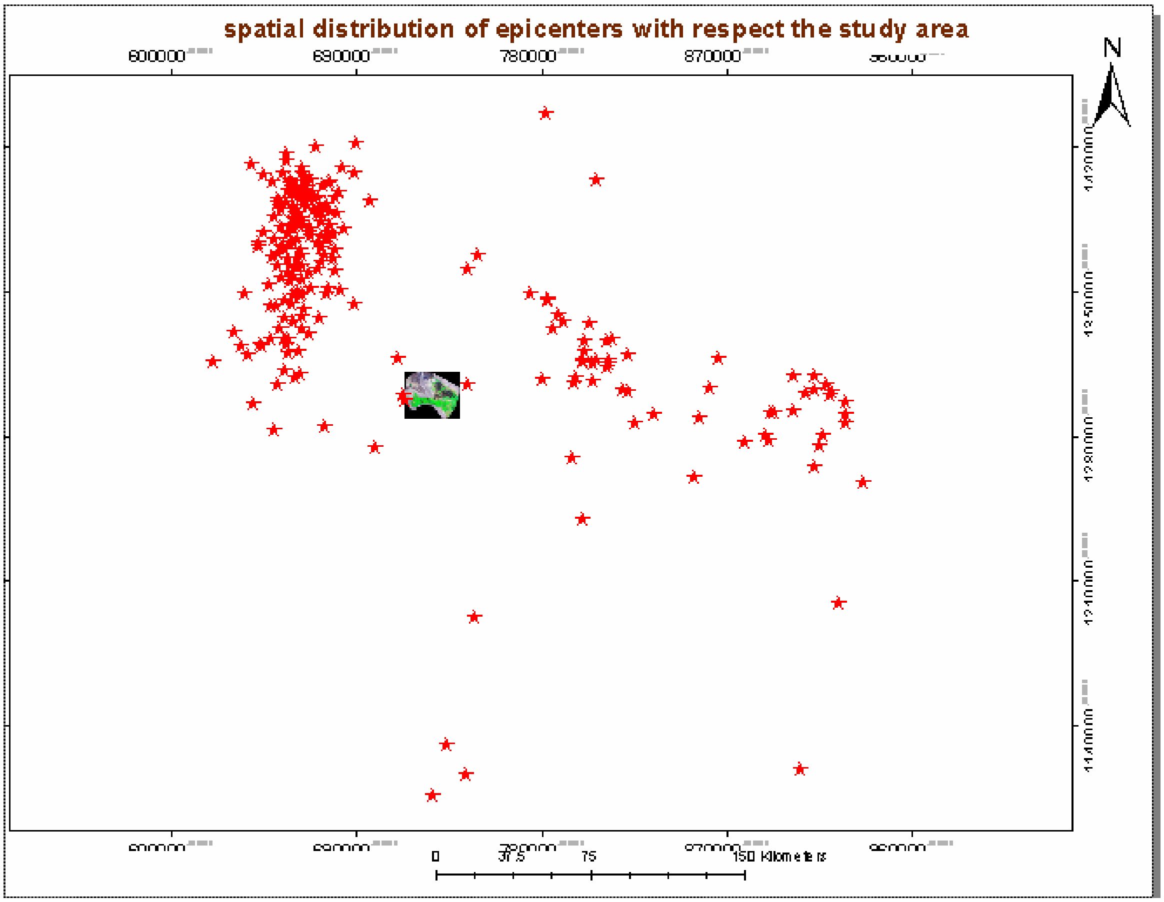
In this study, earthquakes of magnitude >= 4 are considered for thematic mapping, because it is an earthquake of magnitude >=4 that have energy to significantly shake or affect an engineering structure or building. Earthquakes outside my study area also considered because an earthquake, whose epicenter is not in the study area can also affect engineering structures in my area depending on the energy released during rupturing. The source of the data is from Pierre Guan's book and from U.S Geological Survey Earthquake Data Base.

Data source

1) A catalogue from Pierre Guane's book seismic record from 1906-1977,
2) U.S Geological Survey Earthquake Data Base, data range=1960-2006;month:01/day;01 to month:05/day: 22;magnitude range: 4-10;data selection: historical and preliminary data, llatitude: 13.000E-10.000E;longitude: 43.000E-40.000E,catalogue used: PDE

From the catalogue data, we can conclude that the foci of the earth quakes is less than 70km,which implies that the earthquakes are shallow depth earthquakes of divergent plate boundaries caused due to extensional crust and rifting, this crust is gradually being stretched and thinned, arouse studies show that the area is characterized by normal faulting, which are sites of the shallow earthquakes, down thrown fault block (central graben), the faults act as pathways for basaltic magma and this upwelling of hot magma causes uplifting.

Fig. 4.6



spatial distribution of epicenters with respect the study area
N
0
37.5
75
150 Kilometers

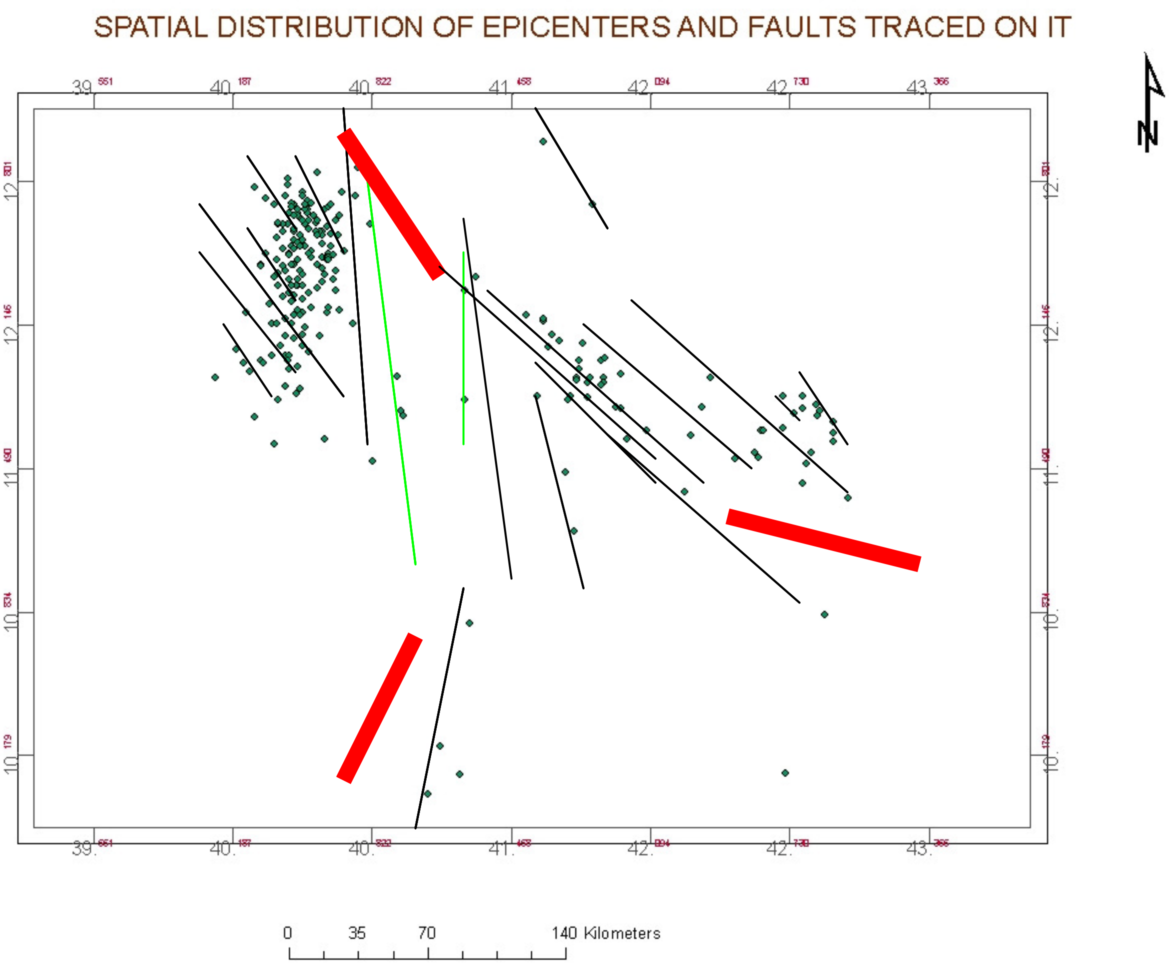

SPATIAL DISTRIBUTION OF EPICENTERS AND FAULTS TRACED ON IT
N
0 35 70 140 Kilometers

Fig. 4.7

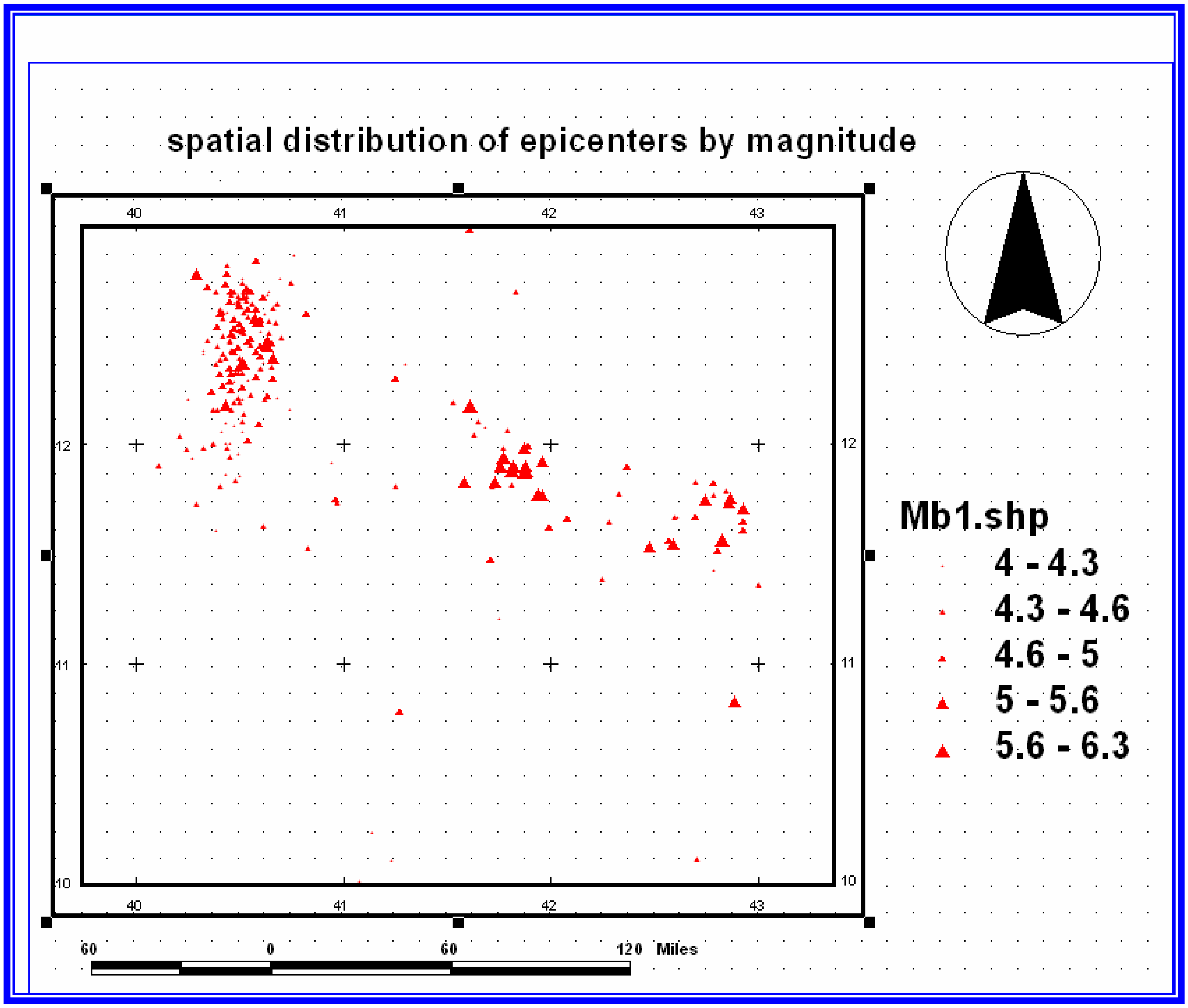


Fig. 4.8
The above maps show the geographic distribution of earthquake epicenters in and around my study area, here earthquakes of magnitudes greater than 4(Mb) are considered, because earthquakes of magnitude above 4 have significant influence on engineering structures, the area between the two green colored lines(faults) is the tendaho graben, which is the continuation of the Red sea rift, the thick red line north of tendaho graben shows direction of the Red sea rift, the epicenters align along straight lines which means the movements took place along these faults, and the study area is located area is located in the Afar triangle(depression).

I focus on Semera area because it is the area,where there are towns(Semera,Dubti,Asayta and Logya) and dense population and buildings and earthquake is hazardouse only in areas where there are people and cultural activities.
From the above figure we can say that there are no earthquake records higher than Mb=5, there are events with Mb>5 north east of the study area at Erta' ale and Teru Boina areas and on the eastern side near Serdo and Djibiti; this result is similar to the result of micro seismic investigation done by Aquater group who studied the area for hydrothermal energy development by drilling upto 2kms depth in Tendaho area. The higher magnitude events, though it is far from my area it has high energy,hence the waves can reach upto semera.for exaple in September 2006,people in semera witnessed that they felt the earthquakes,which ruptured about 200 km away from semera,at Erta'ale area,which was maximum 5.6 in Richter scale,

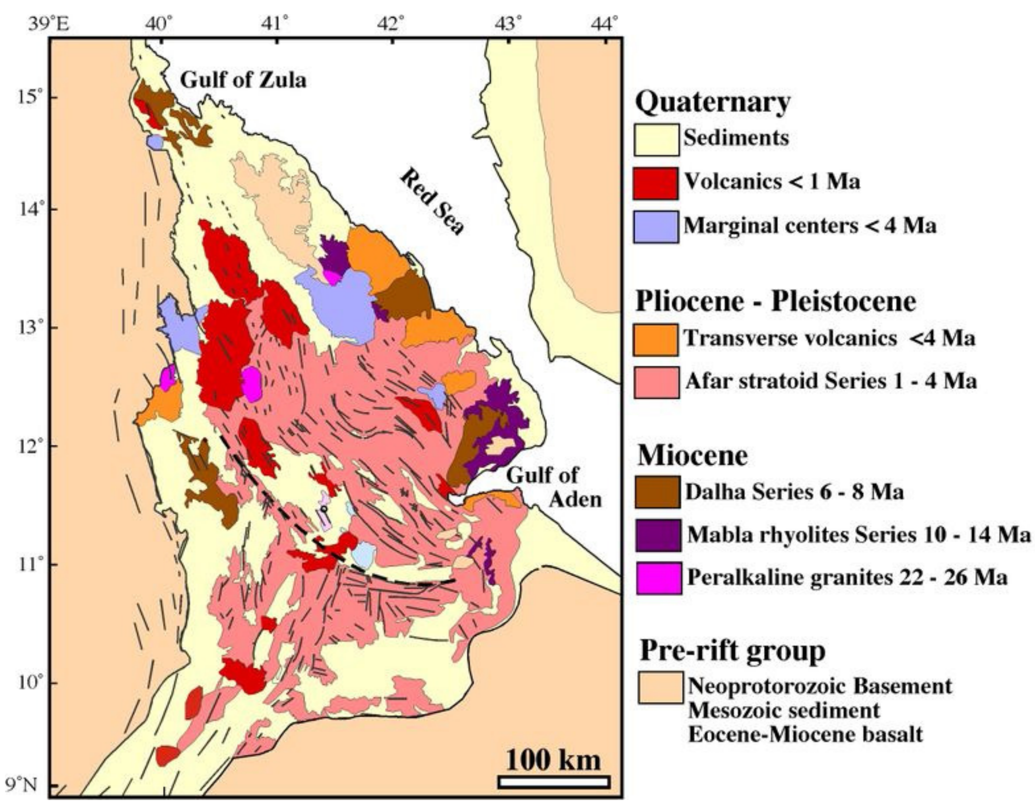
CHAPTER-5

The local geology's response to, and modification of, Earth- quake ground shaking

5.1. Regional Geology

The Afar region is an area of active extensional tectonics and volcanism, where the Gulf of Aden, the Read Sea and the Ethiopian rift systems radiate. The peculiarity of this area is that it represents. together with Iceland, an emerged boundary between diverging plates and the only emerged RRR type triple junction(Mckenzie and Morgan,1969).

FIGURE 5.1Geological map of central Afar, by Alebachew and Abdelselam.



The Afar Triangle is not a usual triple junction. Only three of its three rift systems(Red Sea and Ethiopian) meet together, whereas the third(gulf of Aden) does not directly join the other two arms of the junction. It penetrates landwards with the rifts of Asal,Inakir and Manda which roughly parallel the Red Sea system for one hundred kilometers, and then branches out as a Nw-trending horsetail merging into the complex extensional structure of the northern part of the Afar Triangle.

The rift system along the Red Sea forks southwards with one branch(eastern) which continues along the southern Red Sea, while the other(western) penetrates on land at the northern apex of the Afar Triangle and produces an almost uninterrupted row of volcanic centers. Tectonics and volcanism are active only in the latter ramification. The Ethiopian rift also splits in
Slightly diverging branches as it approaches the Afar region, where it joins the Red Sea system (Tendaho rift) near Lake Abhe. Here some of the major lineaments of the Tendaho Rift and of the main branch of the Ethiopian Rift define an arcuate, rather than angular connection indicating some kind of continuity.

5.2. The local geology response to, and impact of,

Earth- quake ground shaking.

Soil investigation and laboratory testing of Semera was conducted by Building Design Enterprise, Material testing Department, for foundation studies of projects built in Semera, sampling was done up to 10m depth by bore hole and test pits up to 3.5 m depth. Here I take as an example the foundation at schools and meeting halls as there are gathering of people which aggravates the hazard that can come from earthquakes; hence the available data of foundation study for Second cycle boarding school, council office and guest house, crop's camp, trade industry and transport bureau, cultural center& museum and Disaster prevention projects are considered.
The main focus of the study is on Semera town as it is the capital town of the Afar regional government. The future plan made by NUPI shows that its area will grow from 876 ha at present to 2224 ha by the year 2025 and its population will grow to around 18,000 with annual growth rate of 3.7%. The town is at the center of the active rift axis which recently showed new ocean opening with maximum 8 m wide and 60km long fracturing north of the town, in which the epicenter locations showed to migrate towards Semera.

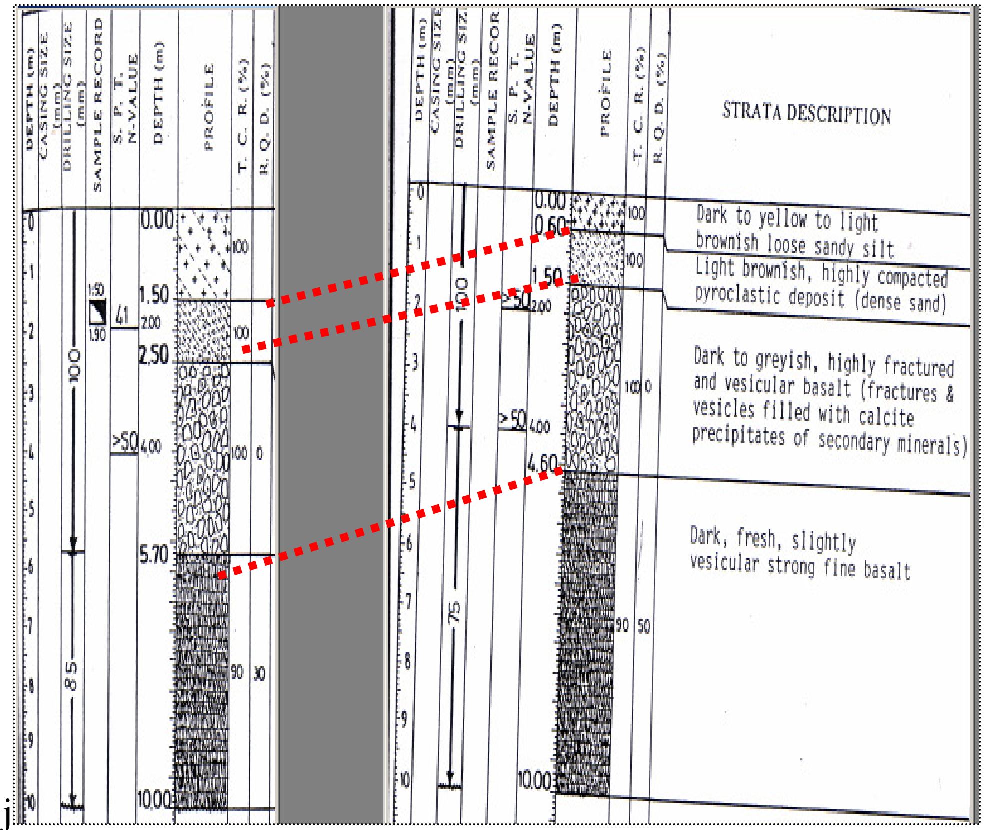
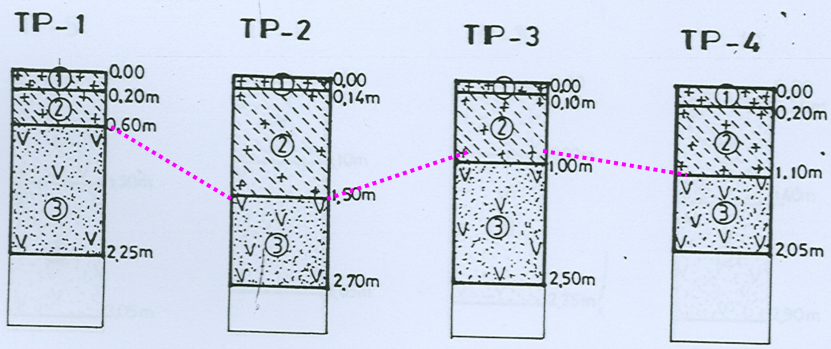


Fig. 5.2 Boreholelithology of two bore holes east-west of the corp.'s camp in semera.

The area is dominated by flat morphology, hence there is no landslide that can be triggered by earthquake.9 boreholes, ranging in depth from 7.00 to 10.00m were drilled By BDE for geotechnical study of the foundation conditions of the Corp's camp project in Semera, it shows that the most top parts of the area is covered by pyroclastic material, constituted by slightly sandy silt and silty sand with occasional fragments, underlying this is a strong vesicular basalt, more fractured and vesicular at the top was encountered in each boreholes and then it becomes more strong with a little or no vesicles. The top fractured and vesicular basalt is filled with secondary mineral calcite precipitate, sometimes in wide fractures, and large vesicles, it forms a calsitic rock structure of its own (nodular fixture).The area is characterized by recent faulting, further more, the presence of active volcanoes north of semera (Erta Ale) proves the formation of Aden series that has not yet been completed, this shows that when the magma enters in to new phase, which will be followed by change in P-T condition and in Density too, this leads to pressure or stress accumulation in the rocks, as the less denser magma tries to push upwards, the surface rocks which are cool relative to rocks at depth will not be strained, rather break to relieve from the stress along formerly formed cracks(faults),energy will be released during this rupturing and shake the ground in different fashion.



N°	Soil type	Consistency
1	friable light grey coarse slightly sandy SILT	loose
2	grey poorly graded coarse silty SAND with indurated pyroclastic material	dense to very dense
3	whitish grey completely weathered and partially decomposed, very thinly bedded pyroclastic material with occasional strong bands	weak

Fig. 5.3 Hand dug test –pits in Semera town

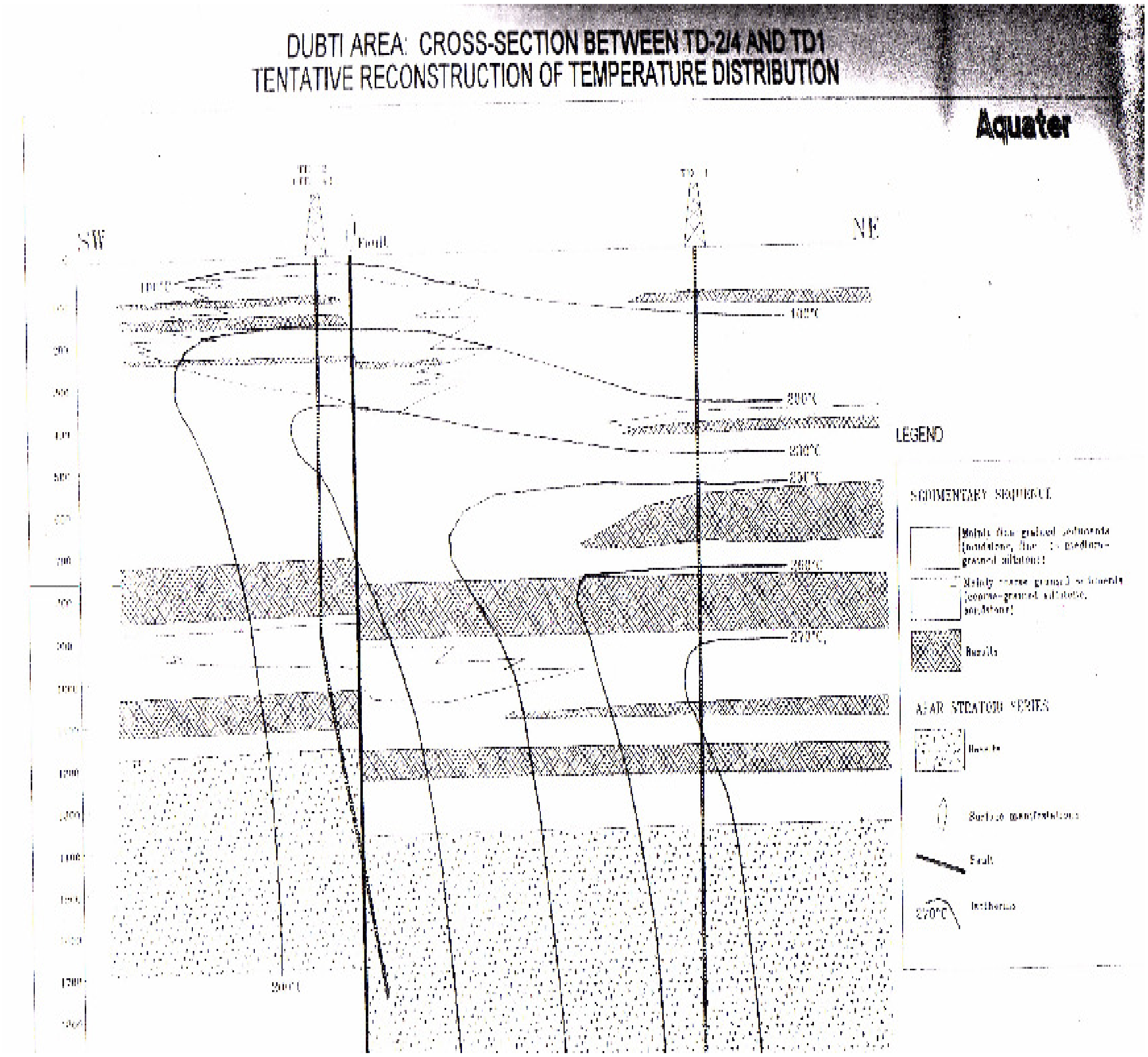
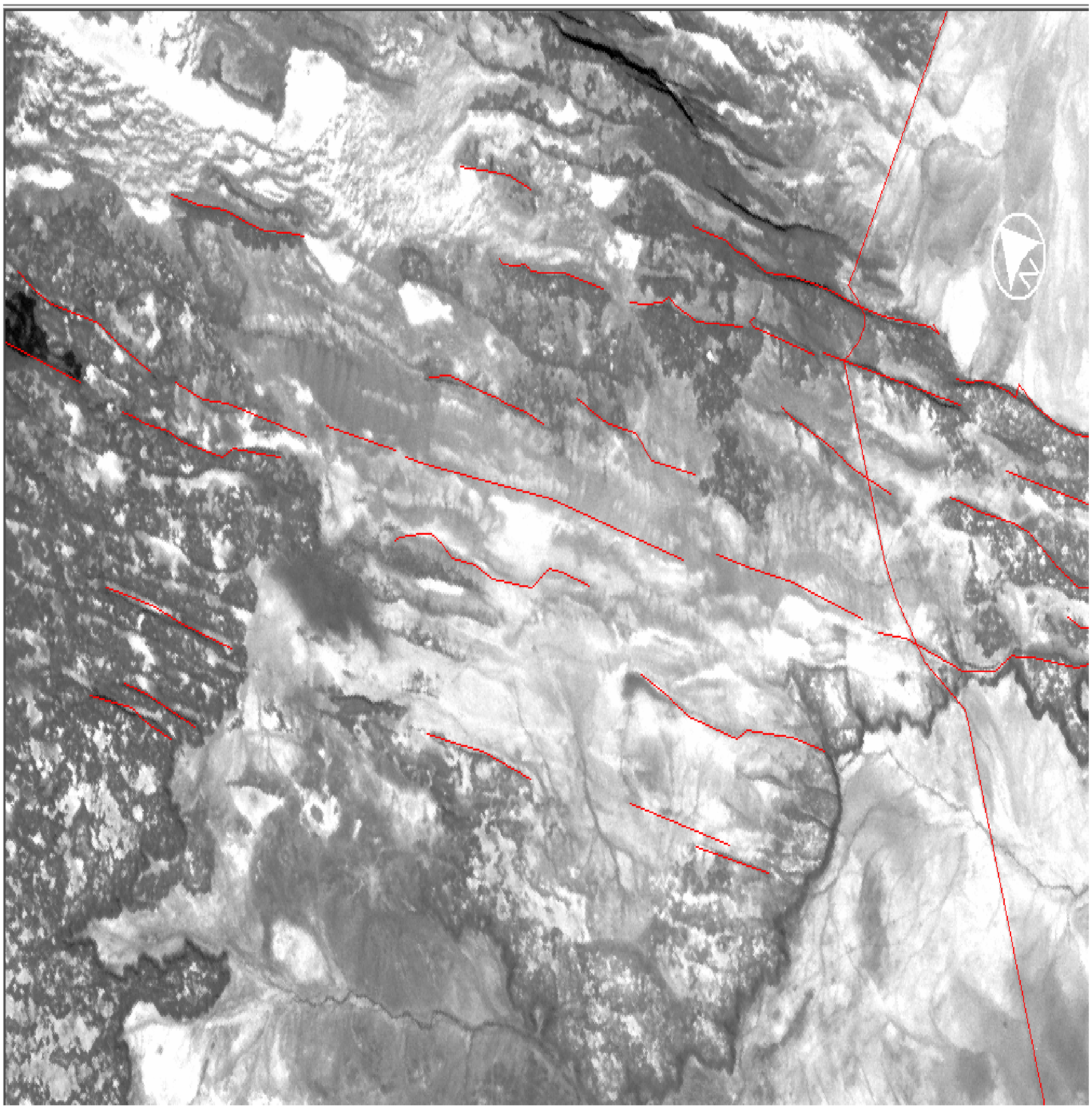


Fig.5.4 conceptual model from a bore-hole dug up to a
depth of 2000meter by Aquater group

5.3 GEOLOGY OF THE STUDY AREA

The study area is located with in the NW-trending Tendaho rift(graben),which is the southern portion of the Erta Ale-Manda Hararo rift system,Which extends the active tectonics of the Red Sea to the south.The borders of the Tendaho Rift are constituted by the afar stratoid series,the study area is constituted of lacustrine and alluvial deposits and with post-stratoid basalt flows,this filling is topped by recent volcanoes.

Figure5.5. shows high resolution camera photograph from NASA, of Semera and the faults traced on it



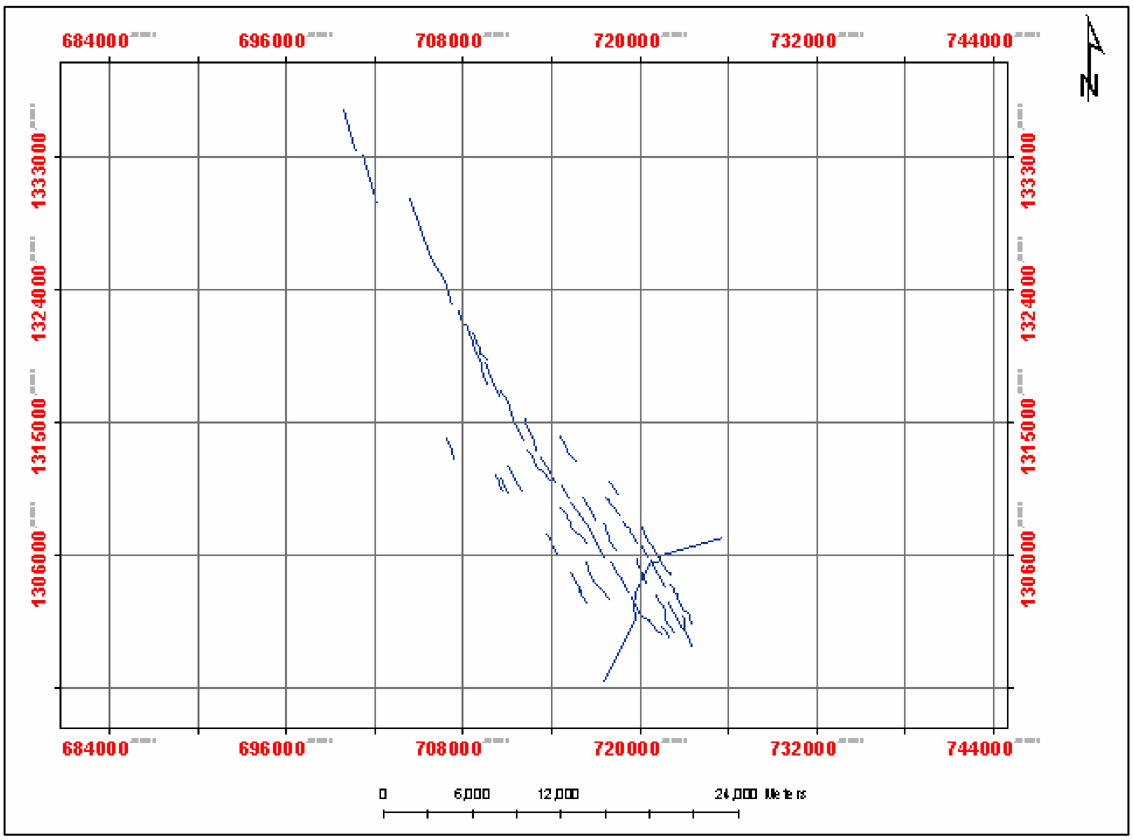


Figure5.6 Fualts traced and from figure5.3

5.4 FIELD REPORT

GCP	Longitude(x)	Latitude(y)	Altitude(m)	Downthrow(m) for faults	expected	real	remark
1AA	1307499.87	727387.37	376		Road intersection		Asab and asayta roads intersection
1AB	1305476.87	720804.12	411	8	fault	Active fault	Fault with 8m down throw of the eastern block and grey color at bottom
1AC	1305753.12	721267.37	425	3	fault	fault	Fault with 3m down throw of the eastern block
1AD	1297525.12	717557.12	392				Logya river bridge
1AE	1202042.87	719622.62	404			About 60 m difference in elevation	Boundary of semera horst and the graben near the road toward logya,
1AF	1297610.12	726694.62	378				Dubti town, at the corner of the fence of Tendaho farm, fluvo-lacustrine sediments
1AG	1294014.62	728891.87	Is not checked				The bridge crossing Awash to tendaho farm, Beyahile no.1
1AH	1304546.12	731140.12	376				Mosque(shiek habi bi)a road that branches out to geothermal energy camp in tendaho
1AI	1301471.25	740449.75	is not checked				End of the road towards Afsmbo,in the study area.

Table 5.1

Other measured points

2AA	1304418	72719181	428				Beside the tower in the apartment in front of the water resources office
2AB	1304175	72718892	433				Beside telecommunication office semera
2AC	1303619N	72718540E	427	3			First fault in the direction to logya in semera
2AD	1302876N	72718437	423	5			Second fault on the ridge, towards logia in semera horst
2AE	1296807	72715614	399				Logyya,Agip hotel compound

Field observation

There are two major geological exposures in the study area, 1) sedimentary deposits(fluvo-lacustrine according to report by Aquater group) ,which covers most of the graben area that extends from logya town to the end of the Tendaho farm, and 2)Recent lava flows which covers most of the semera horst areas, with some scoria deposits on the eastern part of the horst. Though reports by other researchers describe the sediments as fluvo-lacustrine deposits, In logyia town I found that the mud used for house building was found to be covered by salt(NaCl) after the water was evaporated, I cheeked this by testing. From this I suggest that there are also old marine deposits as continuation of the Afdera salt plain.

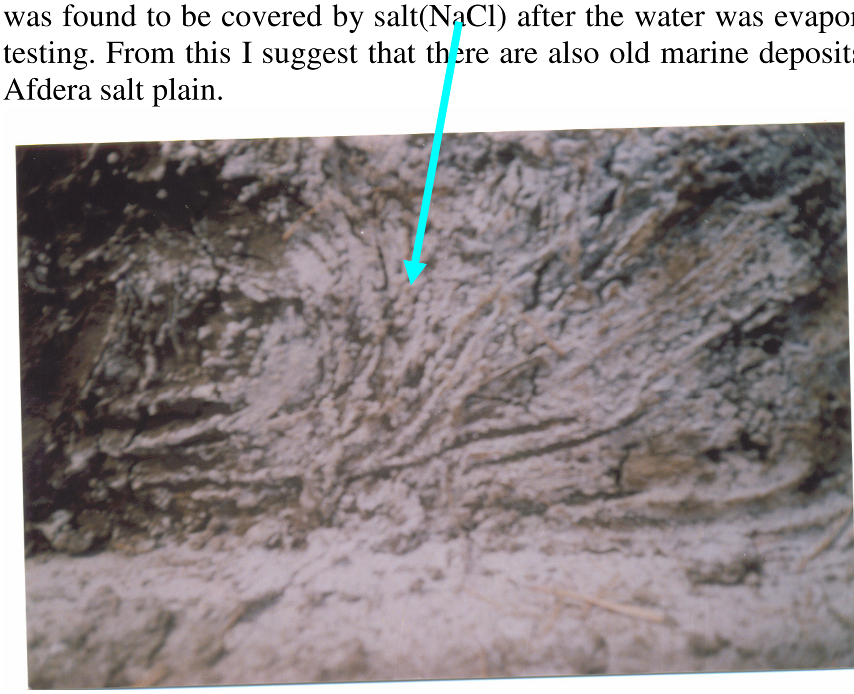


Fig. 5.7 salt on a wall of a house in logya.

We were unable to see faults in the graben covered sediments, but we can infer that there is fault buried in the sediments of Tendaho plain because we observer a fissural lava poured on the sediments, in an elongated shape.
The only area where we were able to observe mappable fault scarp is in semera horst, the blocks are tilted in two directions, NW and SE of semera town with maximum down throw up to 10 meters, we were also able to identify from high resolution camera photographs.

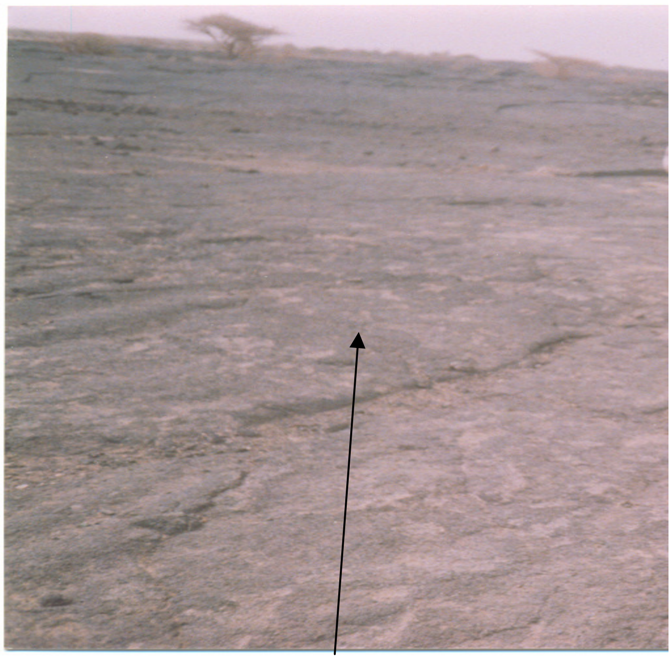


Fig. 5.8
Basaltic lava, poured out of fissure on fluvo-lacustrine deposites,2km west of Semera..

fig. 5.9
Erta 'Ale volcano From http:/BBC news.com new ocean opening.

Fig. 5.10 A fault created in September 2005,after a swarm of earthquakes,the source is the same as the above figure.

Fig. 5.11 Dam site on the Awash river

Fig.5.12Two faults on the eastern part of Semera,the distance between the two faults is approximately 400meters.

A fault at the
 western par
t of Semera

The ridge o
f Semera

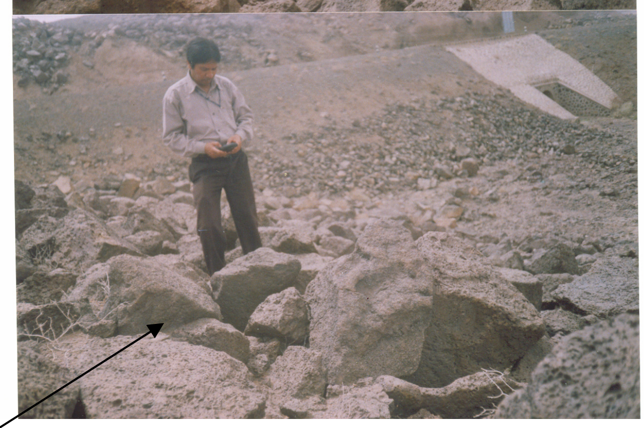


fig. 5.13 Pieces of boulders fomed by extrusive lava flow at the ridge of Semera,

Fig. 5.14 Fluvio-lacustrine deposits at Dubti

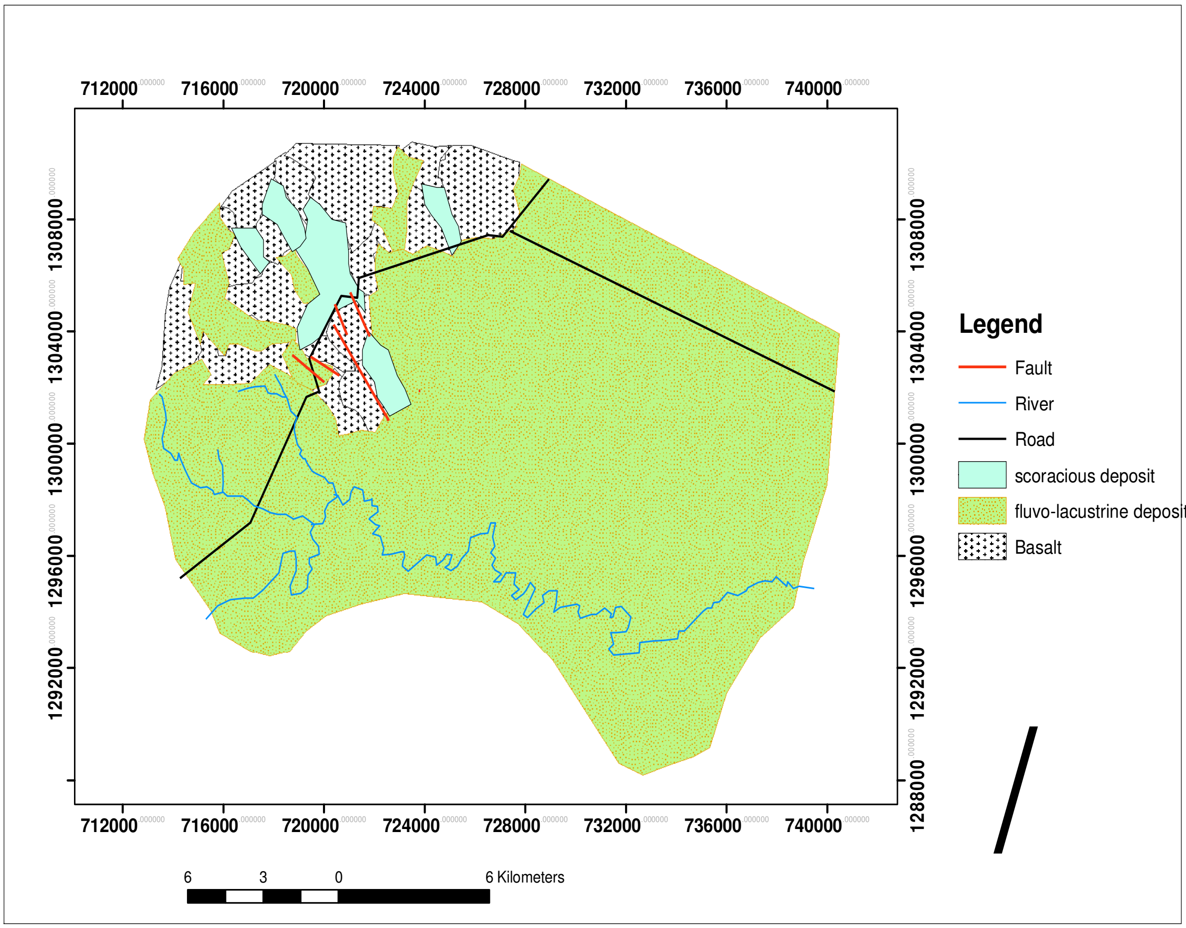


Figure.5.15 Geological map of Semera area,Modified from geological map of tendaho Graben by Aquater group.

Advantages of GIS techniques over other methods of mapping is that, With GIS techniques we can calculate the area of each geological unit,it's primeter, length of fitures, a nd some statistical analysis.

OBJECTID*	Shape*	ID	Shape_Length	Shape_Area
1	Polygon	0	18899.645829	9423418.407924
2	Polygon	0	5901.720577	1546199.018666
3	Polygon	0	10513.711532	3117990.031751
4	Polygon	0	5954.734731	1968391.643498
5	Polygon	0	91045.330772	335205831.065311

Length of river=39.148 km

Area of basalt=61.385678Km^2

Area covered by lacustrine deposits= 351.281630km^2

Area covered by scoracious basalt= 15.447398km^2

Total area=428.114706 km^2

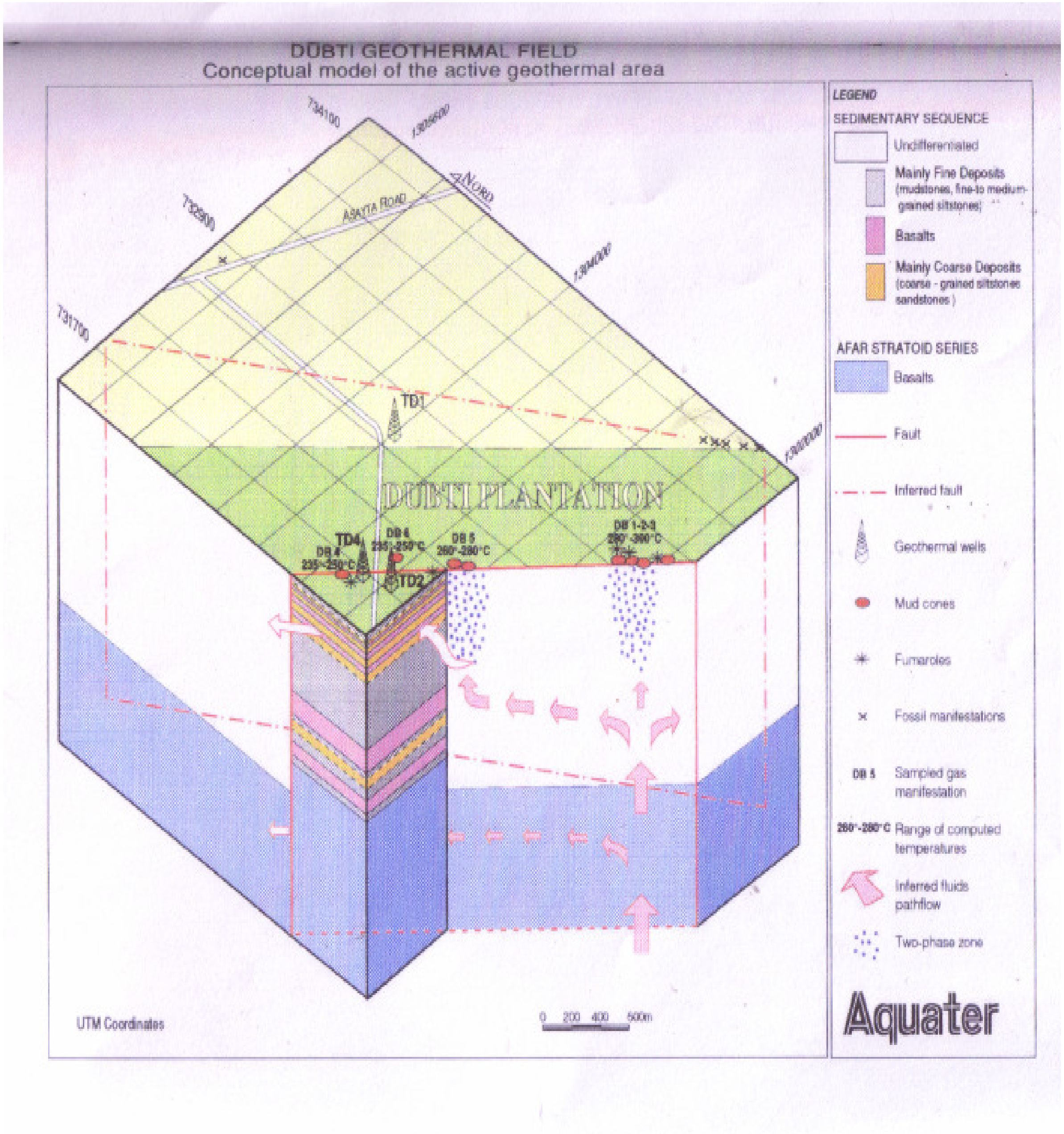


Fig 5.16

A detailed investigation through Geophysical survey and drilling survey was conducted for geothermal energy development by Aquater,three deep wells were dug at the tendaho irrigation farm,From the investigations it is found that the maximum depth of the rift floor has been estimated at about 1600m,by geoelectric prospections(aquater,1980).well-1 reached the volcanic basement at 1400m,whereas geoelectric prospecting indicated only 800m.There are active faults which define NW-SE elongated blocks,with a horst at semera area and graben from two sides,most of the faults show steep inclination,their intersection with the topographic surface,points to the fact that most of them are very close to the vertical,the vertical throw is few meteres with the only exception of some larger border faults,as pointed out by previous work of photointerpretation(Papini,1993),o rdered by aquater.Evidence of active NW-striking faults is also in the sediments with in the Dubti plantation,these consist of aligned steaming grounds,fumaroles and hydrothermal deposits.

GEOLOGY OF SEMERA

The town of Semera is founded on a flat area made up of fissurally erupted lava forming local small horst streuctures with distinctive linearly marked NE-SW terrace-forming escarpments.Geomorphologic features surrounding logiya are characterized by a flat locally undulating topography formed by alluvial deposits and chains of volcanic hills toward the west

5.5 Amount and level of ground water level (liquefaction) and Slope

In all the bore-holes and test-pits dug for the purpose of investigating the foundation of various buildings in Semera town, no water was encountered, boreholes were dug unto the depth of 10m,though it was intended to dig unto 15m depth they could not go beyond 10m because of the difficulty of digging the hard rock, test-pits were dug up to 3m depth, though it was intended to dig upto 3.5 m depth with hand tools, hard ,they were unable to dig beyond that, due to the hard nature of the rock and no ground water is encountered in all test pits and bore holes, this shows that there is no a threat from liquefaction in semera in the 8 hectar master plan of expansion of the town intended to serve up to the year 2025 because the boundry of the town is on the top of the horst ,after 50 years ,it may expand down to the graben in the direction of Logya town(towards the west), towards Serdo town(towards the east), towards the north is a horst which is a continuation similar to the litho logy, where present time Semera is founded, the areas on the west south and west are situated in the tedndaho graben covered with lacustrine deposits and with in the floodplain of the awash river and a tributary of awash, the logya river. Four deep wells
Were dug for detail investigation of geothermal energy exploration by Aquater to a maximum depth of 2196 km TD-1 well, in all the wells the well stratigraphy results show that sedimentary deposits from 40m to 600m of fluvo-lacustrine successions of brown to grey siltstones, sound rocks called stratoid series basalts(<4Ma) are encountered below the sediments; this shows that there is thick aquifer in the graben, hence building big structures in the graben area will be unsafe in terms of liquefaction and soft foundation, the soft foundation will increase the ground acceleration.

There is no significant slope in the area except the margins of Semera horst ,hence we can say, there is almost no land slide that can be triggered by an earthquake. hence buildings in towns located in the graben like Logya, Asyta, Dubti will be affected more from weak foundation factor than Semera.

5.6 GROUND WATER

The design criteria for service reservoir recommends that extended storage be provided adequate cooling time for the hot ground water ,a total of 24 hours' additional storage has been selected to be constructed adjacent to the elevated reservoir.

For the development plan area of Semera,a bout 9.6 km of pipeline is needed for the year 2015,a further 5.5 km for the year 2025.extention areas of the town would require further investments in pipelines: 14.8km by the year 2015 and an additional 8.4km by the year 2025.Minor distribution pipes(1"diameter) will need to be laid as the demand for connections materializes. It is anticipated that 52 km of minor distribution pipes will be needed by the year 2015,with a further 34 km by the year 2025

CHAPTER-6

Type and use of buildings and life lines constructed in the area.

6.1. Building codes for Semera

According to the Ethiopian Building code standard prepared by Ministry of Works and Urban development, the effective ground acceleration in seismic zone4, which covers the whole rift valley in Ethiopia, a_g **=0.03.** All types of buildings satisfy must:- structural simplicity, uniformity and stiffness, Bi-directional resistance and stiffness, torsional resistance and stiffness, diaphragm action at storey level and adequate foundation. For the purpose of this standard the country has been subdivided in to four seismic zones, depending on the local hazard, by definition, the hazard within each zone can be assumed to be constant. For application of this standard, the hazard is described in terms of single parameter, i.e the value of a_g of the effective peak ground acceleration in rock or firm soil, henceforth called "design" ground acceleration." The design ground acceleration for the Seismic Zones corresponds to a reference return period of 100 years. To this reference return period, an importance factor I equal to 1.0 is assigned. Seismic zones with a design ground acceleration a_g not greater than 0.05g(zone 1,2) are low seismisity zones, for which reduced or simplified seismic design procedures for a certain types or categories of structures may be used. In seismic zones with a design ground acceleration a_g not greater than 0.03g the provisions of this standard need not be observed.

Basic requirements

1) The earthquake motion of a given point of the surface is generally represented by an elastic ground acceleration response spectrum, henceforth called "elastic response spectrum", Normalized elastic response spectra are shown in the following figure, which represents the free field ground acceleration response.
2) The horizontal seismic action is described by two orthogonal components considered as independent and represented by the same response spectrum.
3) Unless specific studies indicate otherwise, the vertical component of the component of the seismic action should be represented by the response spectrum as defined for the horizontal seismic action, by scaling the ordinates by a factor of 0.7.
4) For the purpose of this standard seismic forces are determined on the basis of the design spectrum defined in section 1.4.2.2(4)EBCS-8.

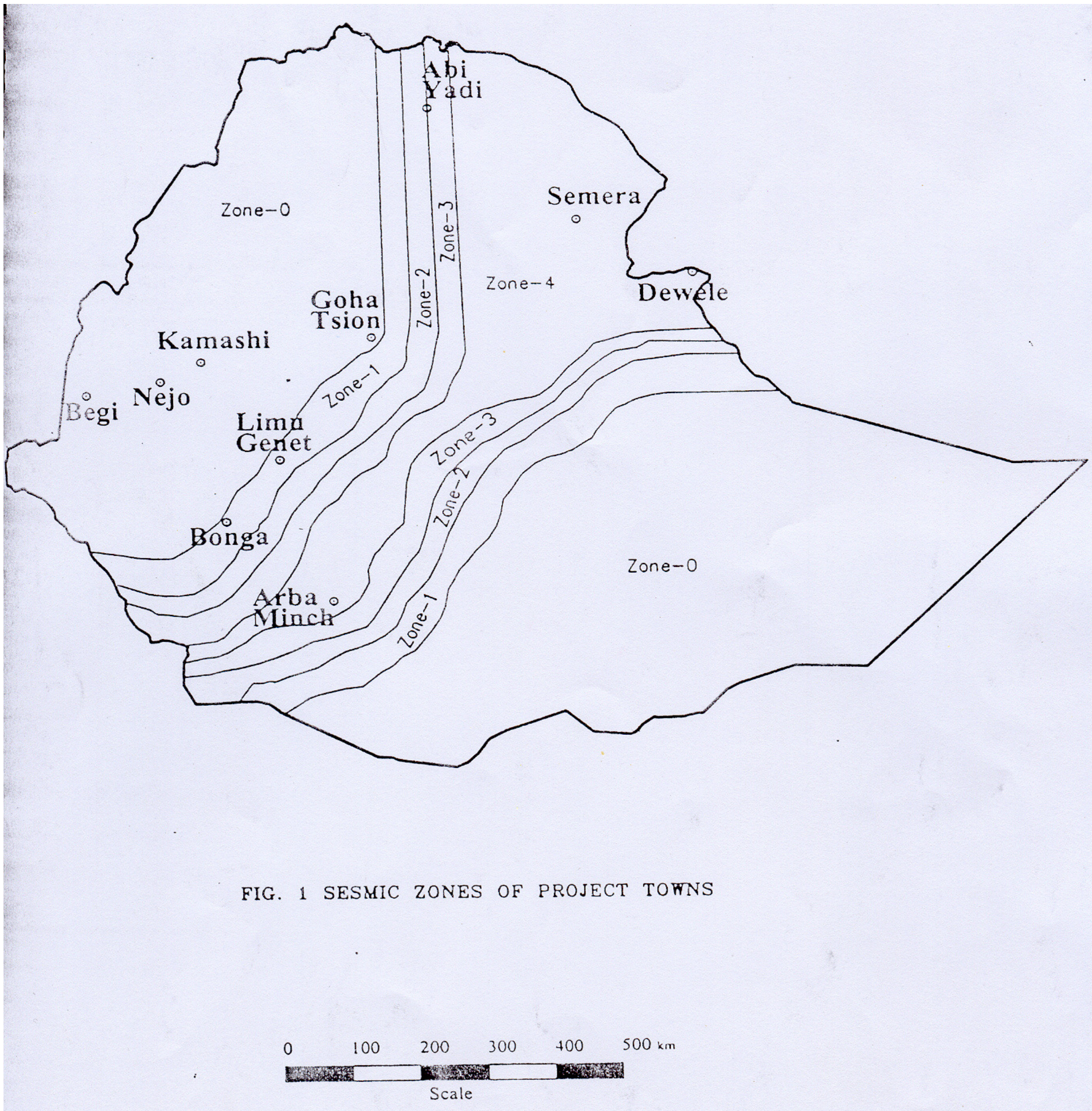


fig. 6.1

Table6.1. allowed number of storey above ground.

Type of structure	Number of storeys allowed in zone 1,2,3	No. Of storeys allowed in zone4
Unreinforced masonry	3	1
Reinforced masonry	4	2
	5	3

Fig. 6.2
A water tower in semera, vulnerable to earthquake hazard due to its height and narrowness.

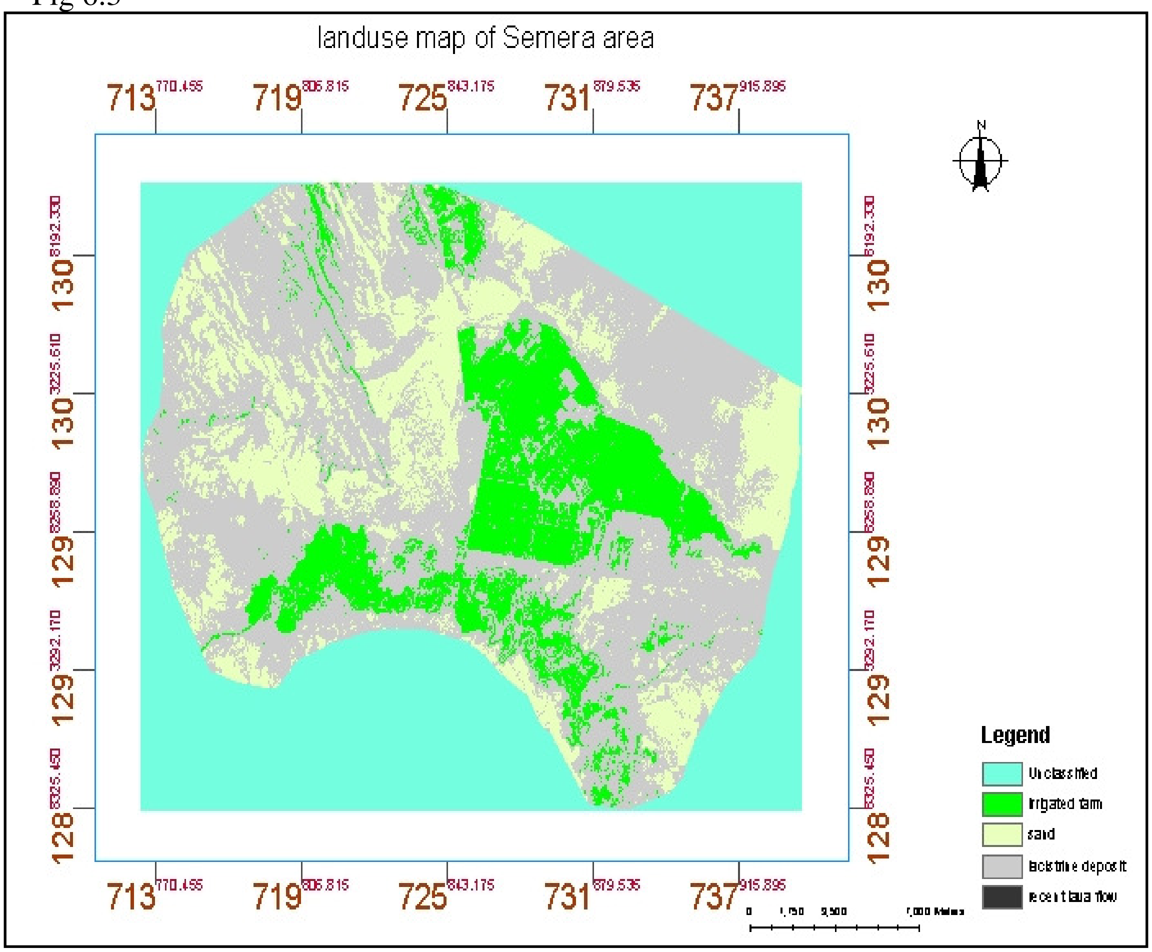
Table6.2. Planned projects for semera

no	projects	Budget Birr
1	Veterinary laboratory	2,198,921
2	Crop protection center	239,888
3	Rural technology promotion center	598,233
4	Semera town green area development project	176,000
5	Semera town emergency water supply project	1,363,640
6	Semera town power supply project	10,000
7	Semera town bus station study and design	10,000
8	Junior secondary school construction	360,000
9	Senior secondary school construction	200,000
10	Radio education studio construction	241,932
11	Junior nurses training center	608,000
12	Teacher training center study and design	40,000
13	Regional health laboratory construction	145,000
14	Primary school construction	62,000
15	Semera health center construction	400,000
16	Warehouse construction	400,000
17	200 residential houses construction	37,790,957
18	Semera town secondary roads construction	50,000
19	Library and archives construction	85,000
21	Museum and cultural center construction	145,000
21	Semera small stadium construction	675,010
22	Regional government offices construction	1,098,000
23	Justice bureau construction	1,340,000
24	Civil service agency bureau construction	1,084,000
25	Finance bureau construction	860,000
26	Supreme court bureau construction	1,625,000
27	Planning and economic development bureau	860,000
28	construction	2,772,000
29	Works and Urban development bureau construction	1,382,000
30	Audit bureau construction	844,000
31	Trade, industry and transport bureau construction	844,000
32	Disaster prevention bureau construction	163,000
33	Police training school	2,049,000
34	Presidential palace	810,000
35	Purchase of office furniture for the bureaus	25,000
	Semera town municipality study and design	
	Total	**61,555,581**

6.2. Land use

As it is shown in the following figure, the land use type in the study area are, flood plain, irrigated farm land, browsing land, bare land, mostly life is based on the awash river and its swampy areas, in that arid area the only source of water is the awash river, which gets its water from the highlands, all the towns (Semera, Logya, Dubti) in the area are established near the awash river, as the awash is the only source of water.

Fig 6.3



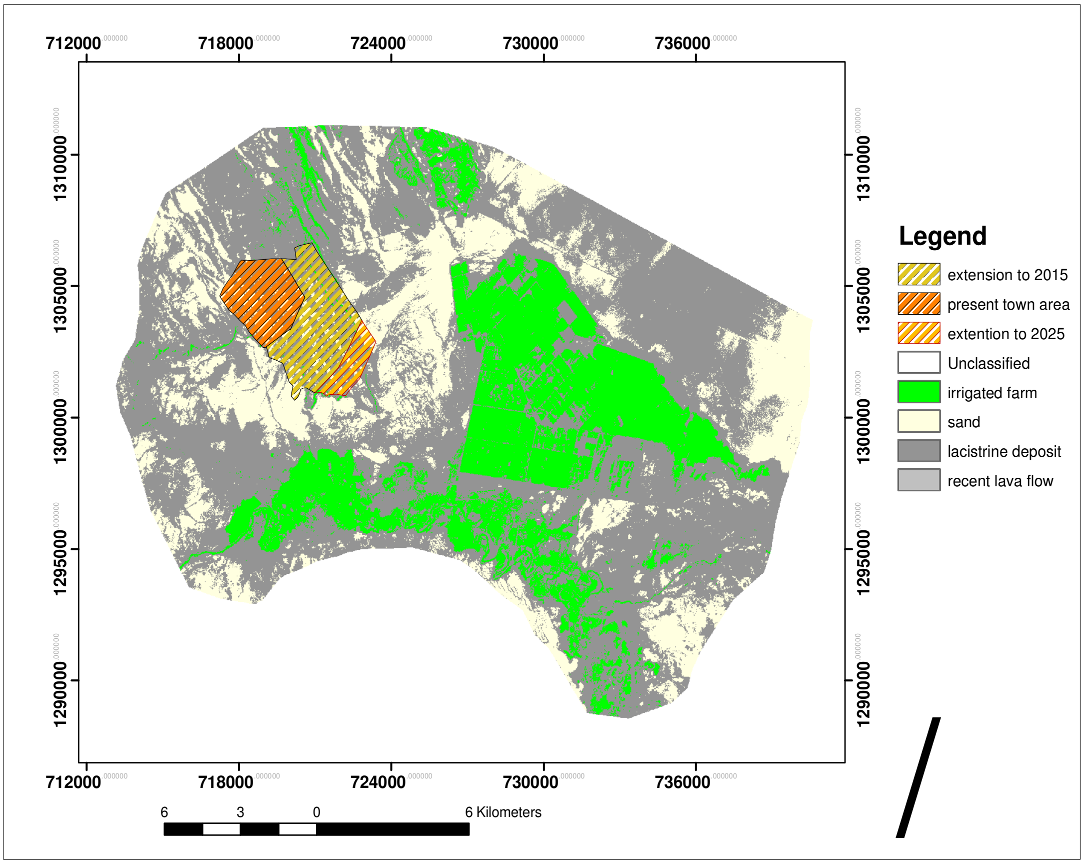


Figure6.2 Land use map of Semera area that show,Sem6.2 Land use map of Semera area that show, Semera town plan up to the year 2025 according to National Urban Planning Institute.

Development plan based its population forecast for Semera on 60% of the applicants for plots, plus the movement of the 486 workers in regional bureaus when the capital city of Afar was shifted from Asaita to Semera, The NUPI gives a 1997 population of 3678,growing to 5200 in2002 and 523 in 2007 based on the report of regional bureaus, there are no meaningful figures of population done by CSA for Semera.

The NUPI forecast the population to grow according to three variants, with annual rates of 5%,6% and 7%,starting with 3678 in 1997.

Table 6.3. Population forecast-semera

Horizon	2005	2010	2015	2020	2025
Growth rate p.a.to next horizon	4.0%	3.8%	3.6%	3.5%	
Population	8,439	10,267	12,372	14,765	17,537

The area has low population density, according to survey done by NUPI The area is known for new irrigation projects and two dams are under construction, which are made from soils and rocks ,hence even a small earthquake can result in failure of the dams , hence flooding can occur down the dam area.

Land use map

Semera is on the direct route to Djibouti and Asab, Semera is also placed on a hill at a higher elevation than either Asaita or Logiya(some 7km away),this makes it more likely to have cooling winds and it is expected that this will be another cause of growth in the town's population.

Chapter-7

Discussions, conclusion and recommendation

7.1. Discussion

Detail analysis of shallow earthquake epicenter locations can be applied in active fault mapping, in the study area, though I used only high magnitude earthquake magnitudes for engineering purpose, the epicenters align them selves along the two major faults of the study area, i.e the two faults bounding the Tendaho greben, which is the continuation of the red sea rift. According to the discussions made with scientists who studied the Afar area for many years, the axis of the red sea rift passes along erta'ale ,teru boina, Debahu, then to Semera and Dubti. In the above chapters I examined the area in terms of the nature of seismic waves in the area , in terms of the regional and local geology of the area and the life line situation(population density, building type infrastructure), the buildings in the area are of maximum three storey, steel-concrete reinforced buildings, the foundation in semera is basalt after 2.5 meter depth, rather the buildings in Logya and Dubti towns though they are villas, few houses are ordinary masonry buildings built on soft sediments, hence are vulnerable to seismic hazard due to response of the ground. Senior scientists and engineers say, that, "The cracking due to faulting extension of the crust, rifting (divergent plat boundary), is extending toward semera area. In this area there are vital infrastructures, the Tendaho and Kesem rock and soil dams, the road which goes from the port of Djibouti to Addis Ababa and bridges on the rivers of logyia and Awash river and the airport in Semera can be highly damaged. A small cracking can result in the failure of the dams; kesem and tendaho, and flood hazard could be induced. Due to limitations in data, especially detailed census data of whole study area, I am unable to give weight using statistical or other decision method to the following three maps and produce a resultant map, I have not encountered to a similar work yet, I got this idea from the paragraph, that say, "In GIS at any stage results can be expressed as a simplified map". the seismic intensity map shows some uniformity.

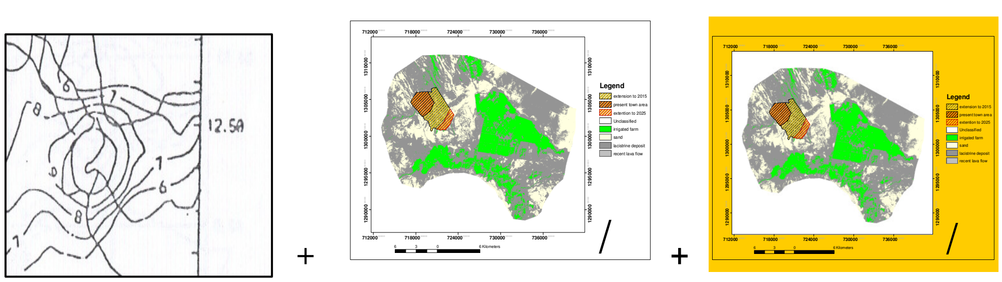


Fig. 7.1
Seismic intensity map + geological map +land use map = earthquake inmduced hazard map.

7.2 Conclusion

-The city of Semera in Afar Region is located in one of the most active seismic zones in Ethiopia and east Africa.

-Intensity contour maps show that the earthquake intensity of the study area is VIII and IX in modified mercalli intensity levels Intensity VIII means, damage is slight in specially designed structures, considerable in ordinary buildings, great in poorly built structures and heavy furniture is overturned. Intensity IX is defined as, an earthquake in which damage is considerable in specially designed structures, buildings shift from their foundations and partly collapse and underground pipes are broken. The intensity (destructive power) of an earthquake at specific location depends on a number of factors. Foremost among these are (1) the total amount of energy released: from this we can assess that the structures and buildings in Semera town, how they are planned, we can classify the area for engineering land use purposes. recent volcano tectonic activities in the area show that the rifting can take place in faster rate than what was studied before ,hence the Ethiopian building code standard needs to be updated soon.
-mapping and analysis of epicenters shows that, the higher magnitude earthquakes ($>M_b$ $=5$) are located in the east(Dabbahu) and north west(Serdo) of the study area, but the

60km long cracking is extending toward semera it is 20 to 30 km north of Semera town, this shows that there may be fault induced hazard to the main road and infrastructures

-Detail mapping and analysis of epicenter and focus of earthquakes using GIS techniques is applicable in active fault mapping, because tectonic earthquakes mostly take place along active faults, for example San Andreas fault, the advantage of this technique over conventional methods is that, we can infer a fault buried by sediments and difficult to seeby our eyes by using epicenter locations along that fault and finding that point with the help of GPS in the field.

.3 RECOMMENDATION

Prior to any construction the area must be classified in to land use categories for engineering purpose, as an example in areas of very high hazard we can build buildings from wood,villas from highly reinforced massonery, schools gazering halls etc from timber, and prohibit from building dams, oil reservoirs, nuclear plants and septic tanks, across the axis of the redsea rift.

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GLOSSARY

Active fault:-for many geologists it is regarded as one along which movement has taken place during the last 11,000 years

Aftershock:-A seismic event which occurs, often repeatedly, after an earthquake and which may itself cause damage to buildings, etc.

Earthquake:-motion of earth,tectonic earthquakes result from the release of accumulated strain when brittle failure occurs,this failure coincides with the release of stress on rocks that actually break.

stress

FORESHOCK:-A small earthquake, sometimes occurring in swarms, that precedes a major earthquake(or volcanic eruption).

HAZARD:- a thing that can be dangerous or cause damage, according to Oxford Advanced Learners Dictionary,6^{th} edition,

-RISK:-the possibility of some thing bad happening at some time in the future, a situation that could be dangerous or have a bad result.

Seismology:-The study of elastic(seismic) waves and how they are produced.

Seismograph:- a device which records the seismic information including, geophones, amplifiers and other accessories.

Seismometer:- an instrument used to detect seismic waves, also called
Geophones especially in exploration geophysics.

Seismic zone:-a region of high seismicity.

Seismicity:-the likely hood that an earthquake will be felt in a particular area; i.e earthquakes are frequent in zones of high seismicity(e.g Japan and California).

Seismic wave:-a packet of elastic strain energy which travels away from a seismic source.

Seismic gap:- an area with in active earthquake zone with in which no significant earthquake have been recorded.

Stress:- force per unit area, can be measured if the rocks are exposed.

Strain:-is change in size (volume) or shape, or both.

APPENDIXES

APPENDIX-1

North/lat	long	Focal depth	Magnitude MB,MS, ML,ME	Intensity (Mercalli) scale	location name and coments	Reporting agency
12.7	40.6		5.5		volcanic &seismic activity in Alayata range,severe tremors throughout Afar	ZZZ
11.2	39.7				Felt in Borumieda	
11.5	43.0		6		Felt in Djibuti	
11.5	43.0				Aftershocks in Djibuti	
11.5	41.5		Mb=6.0			
12.03	41.36		Ms=6.0			
12.03	41.36		Ms=6.0		Afar(serdo region)	
11.13	40.74					Pg3
11.35	39.16	33	Me=5.6		Weldia area	ZZZZ
11.57	42.57		Ms=5.5		Ne scarp Asal Rift	ZZZ
11.5	42.1		Me=4		Felt in Yoboki	
					May-sept,3500 shocks recorded, Majeti&Karakorie damaged	

10.50	39.75		Ms=5.7		Felt in wollo	zzzz
10.39	39.91		Me=4.5		wello	zz
11.1	39.3			6	Felt in Dessie	aae
11.51	41.47	40	Ml=5.5		Central afar	zz
11.6	41.4			3	assyita	aae
11.8	41.2			3.5	Dubti-Tendaho	Aae
12.0	41.3			3	Serdo	AAe
11.82	42.70	33	Mb=4.6			

lat	long	depth	Mb	
11.67	42.7	33	,, 5.0	
11.74	42.75	33	5.3	
11.7	42.93	33	5.4	
11.75	42.87	33	5.2	
11.61	42.93	33	4.8	
11.65	42.93	33	4.9	
11.82	42.79	33	4.7	
11.76	42.79	33	4.5	
11.78	42.85	33	4.6	
12.69	40.47	33	4.5	
10.10	42.71	33	4.6	
11.66	42.60	33	4.6	
11.54	42.59	33	5.4	
11.42	42.79	33	4.3	
11.66	42.61	62	4.3	
11.56	42.57	33	4.9	
11.9	42.37	33	4.8	
11.35	43.00	35	4.6	
12.55	40.67	33	4.5	
12.24	40.36	33	5.0	
10.82	42.89	10	5.1	
12.67	40.61	10	4.8	

12.36	41.30	10	4.3					
11.38	42.25	10	4.6					
12.69	41.83	10	4.5					
11.77	41.94	11	6.3					
11.92	41.96	10	5.6					
11.88	41.81	10	6.10					
11.76	41.96	10	5.3					
11.47	41.71	10	4.8					
11.9	41.88	10	5.2					
11.88	41.88	10	6.10					
12.04	41.63	10	4.6					
11.64	42.28	10	4.4					
11.81	41.81	10	4.6					
11.82	41.58	10	5.1					
11.98	41.87	10	5.4					
11.9	41.76	10	5.2					
11.9	41.82	11	6.2					
12.16	41.61	10	4.7					
11.87	41.87	15	6.3					
11.99	41.89	10	4.9					
11.94	41.77	9	5.8					
11.82	41.73	10	5.3					
11.53	42.48	10	5.4					
11.80	41.72	10	4.4					
12.30	41.25	10	5.00					
12.07	41.68	10	4.20					
12.10	41.65	10	4.60					
12.19	41.53	10	4.60					
11.75	40.96	10	4.80					
11.89	41.76	10	5.20					
11.77	42.33	10	4.50					
11.51	42.81	7	4.90					
11.56	42.83	10	6.20					
11.98	41.77	10	4.40					
11.62	40.61	10	4.40					
11.62	41.99	16	4.90					
11.73	42.86	15	5.60					
12.17	41.61	10	5.90					
12.75	40.51	10	4.20					
12.84	40.58	33	5.00					
12.71	40.53	10	4.70					
12.7	40.54	10	4.60					
12.65	40.45	33	4.80					
12.98	41.61	10	4.80					
12.06	41.79	10	4.50					

10.78	41.27	10	4.70					
11.66	42.08	2	4.80					
10.22	41.14	10	4.00					
10.00	41.08	10	4.00					
10.09	41.23	10	4.30					
12.67	40.53	10	4.40					
11.2	41.75	10	4.00					
11.8	41.25	10	4.60					
12.75	40.69	10	4.00					
12.73	40.75	10	4.50					
12.49	40.42	10	4.50					
12.42	40.47	10	4.70					
12.57	40.60	10	4.80					
12.71	40.53	10	4.40					
12.77	40.29	10	5.50					
12.81	40.44	10	4.60					
12.65	40.53	10	4.40					
12.39	40.50	10	4.40					
12.6	40.44	10	4.					

2005/09/21	12.36	40.38	10	4.40	
2005/09/21	12.41	40.42	10	4.60	
05/09/21	12.51	40.51	10	4.60	
05/09/21	12.53	40.47	10	4.90	
09/05/21	11.97	40.24	10	4.50	
05/09/21	12.44	40.39	10	4.60	
05/09/21	12.55	40.50	10	4.80	
,,	12.62	40.66	10	4.50	
,,	12.47	40.45	10	4.40	
,,	11.98	40.32	10	4.40	
,,	12.60	40.42	10	4.40	
05/09/22	12.78	40.44	10	4.70	
	12.15	40.46	10	4.60	
,,	12.50	40.64	10	4.50	
,,	12.70	40.46	10	5.00	
,,	12.65	40.49	10	4.50	

,,	12.73	40.51	10	4.50	
,,	12.72	40.34	10	4.70	
,,	12.27	40.42	10	4.80	
,,	12.63	40.50	10	4.80	
,,	12.60	40.52	10	4.40	
,,	12.05	40.41	0	4.20	
,,	12.7	40.55	10	4.90	
,,	12.69	40.38	21	4.50	
,,	12.47	40.34	10	4.50	
,,	12.42	40.47	10	4.90	
,,	12.52	40.49	10	4.40	
05/09/23	12.28	40.47	10	4.30	
,,	12.55	40.60	10	4.80	
,,	12.57	40.59	10	4.30	
,,	12.58	40.54	10	4.40	
,,	12.51	40.60	10	4.00	
,,	12.64	40.49	10	4.40	
,,	12.20	40.25	10	4.30	
,,	12.57	40.47	10	4.80	
,,	12.59	40.62	10	4.20	
05/09/24	12.68	40.63	10	4.30	
,,	12.39	40.43	10	4.40	
,,	12.73	40.43	10	4.90	
,,	12.64	40.56	10	4.50	
,,	12.86	40.76	10	4.20	
,,	12.6	40.40	10	4.70	
,,	12.64	40.47	10	4.20	
,,	12.68	40.46	10	4.50	
,,	12.61	40.57	10	4.60	
,,	12.64	40.47	10	4.10	
,,	12.67	40.52	10	5.00	
,,	12.5	40.46	10	4.80	
,,	12.57	40.42	10	4.50	
,,	12.42	40.32	10	4.10	
,,	12.61	40.40	10	4.50	
,,	12.29	40.45	10	4.70	
,,	12.67	40.49	10	4.6	
,,	12.69	40.64	10	4.30	
,,	12.41	40.32	10	4.20	

,,	12.57	40.57	10	5.20	
,,	12.62	40.54	10	5.00	
,,	12.45	40.55	10	4.40	
,,	12.54	40.39	10	4.90	
	12.62	40.51	10	4.30	
,,	12.69	40.52	10	4.60	
,,		40.51	10	4.80	
05/09/24	12.35	40.45	10	4.70	
,,	11.90	40.11	10	4.40	
,,	12.47	40.63	11	5.60	
,,	11.80	40.40	10	4.40	
,,	12.30	40.66	10	4.90	
,,	12.48	40.70	10	4.40	
,,	12.09	40.43	10	4.30	
,,	11.86	40.43	10	4.30	
,,	12.39	40.66	10	5.10	
,,	12.40	40.60	10	4.70	
05/09/25	12.45	40.60	10	5.00	
,,	11.60	40.38	10	4.10	
,,	12.26	40.51	10	4.90	
,,	12.42	40.46	10	4.60	
,,	12.35	40.49	10	4.70	
,,	12.22	40.55	10	4.60	
,,	12.37	40.61	10	4.00	
,,	12.00	40.43	10	4.30	
,,	12.25	40.46	10	4.70	
,,	12.35	40.65	10	4.40	
,,	11.94	40.45	10	4.40	
,,	12.32	40.49	10	4.50	
,,	12.05	40.51	10	4.10	
,,	12.20	40.51	10	4.30	
,,	11.85	40.50	10	4.20	
,,	12.00	40.45	10	4.20	
,,	12.10	40.51	10	4.50	
,,	11.98	40.44	10	4.60	
,,	12.44	40.49	10	4.90	
,,	12.19	40.50	10	4.60	
,,	12.15	40.37	10	4.50	
,,	12.32	40.48	10	4.60	

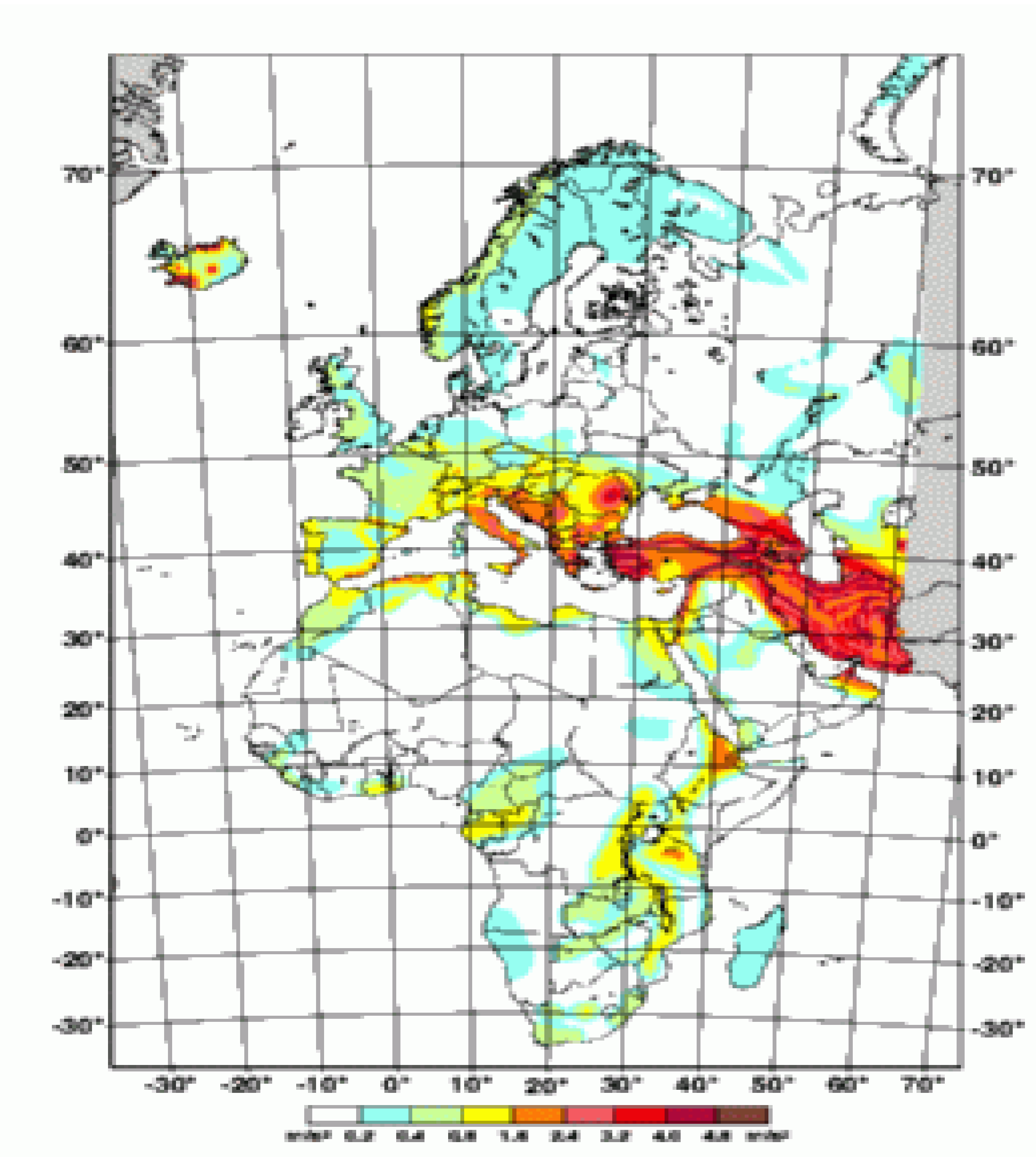
,,	12.58	40.47	10	4.00	
,,	12.64	40.68	10	4.40	
,,	12.19	40.47	10	4.50	
,,	12.13	40.52	10	4.50	
,,	12.09	40.59	10	4.70	
,,	12.50	40.52	10	4.40	
,,	12.08	40.47	10	4.10	
,,	12.21	40.68	10	4.20	
,,	12.37	40.51	10	5.80	
,,	12.45	40.62	10	4.60	
,,	12.49	40.47	10	4.60	
,,	12.21	40.49	10	4.40	
,,	12.42	40.58	10	4.10	
,,	12.17	40.43	10	5.10	
,,	12.00	40.37	10	4.60	
,,	12.44	40.62	10	4.80	
,,	12.32	40.51	10	4.50	
,,	12.20	40.62	10	4.60	
,,	11.95	40.49	10	4.20	
05/09/26	12.62	40.58	10	4.90	
,,	12.45	40.63	10	4.40	
,,	12.50	40.50	8	4.20	
,,	12.32	40.46	10	4.90	
,,	12.48	40.55	10	4.70	
,,	11.83	40.48	10	4.60	
,,	12.47	40.54	10	5.00	
,,	12.31	40.58	10	4.90	
05/09/26	12.46	40.45	10	4.45	
05/09/27	12.15	40.39	10	4.60	
,,	11.93	40.27	10	4.20	
,,	12.56	40.64	10	4.60	
,,	12.03	40.21	10	4.50	
,,	12.34	40.60	10	4.60	
,,	12.29	40.54	10	4.30	
,,	12.22	40.63	10	4.70	
,,	12.38	40.40	10	4.40	
05/09/28	12.32	40.40	10	4.70	
,,	12.55	40.58	10	4.70	
,,	11.72	40.29	10	4.60	

,,	11.97	40.33	10	4.20	
,,	12.44	40.63	10	5.10	
05/09/29	12.42	40.58	10	4.80	
,,	12.15	40.74	10	4.00	
05/10/01	12.60	40.82	10	4.80	
05/10/02	12.02	40.54	10	5.00	
05/10/04	12.46	40.65	10	5.00	
06/02/09	11.73	40.97	10	4.50	
06/02/18	11.52	40.83	10	4.50	
06/02/21	11.91	40.94	10	4.10	

Appendix-2

Magnitude	Date	UTC-Time	Latitude	Longitude
4.5	2005/09/27	10:13:57	12.386	40.580
5.4	2005/09/26	09:33:55	12.378	40.699
5.0	2005/09/25	11:20:04	12.393	40.610
4.6	2005/09/25	10:18:01	12.457	40.521
5.0	2005/09/25	10:02:13	12.305	40.610
4.7	2005/09/25	09:11:38	12.456	40.450
4.9	2005/09/25	08:18:43	12.463	40.601
4.7	2005/09/25	01:11:00	12.360	40.413
4.9	2005/09/25	00:37:28	12.344	40.508
5.6	2005/09/24	19:24:04	12.515	40.502
5.1	2005/09/24	06:58:27	12.417	40.632
5.0	2005/09/24	05:15:34	12.479	40.222
4.6	2005/09/24	04:20:36	12.864	40.164
4.7	2005/09/24	03:57:16	12.563	40.357
4.8	2005/09/24	03:25:28	12.841	40.365
4.8	2005/09/23	20:26:34	12.595	40.440
4.4	2005/09/23	18:01:26	12.414	40.523
4.8	2005/09/22	19:51:52	12.360	40.457
4.8	2005/09/22	13:58:45	12.718	40.530
4.6	2005/09/22	04:28:19	12.713	40.490
5.0	2005/09/22	03:12:34	12.619	40.342
4.5	2005/09/21	20:04:52	12.502	40.419
5.5	2005/09/20	21:23:37	12.643	40.445

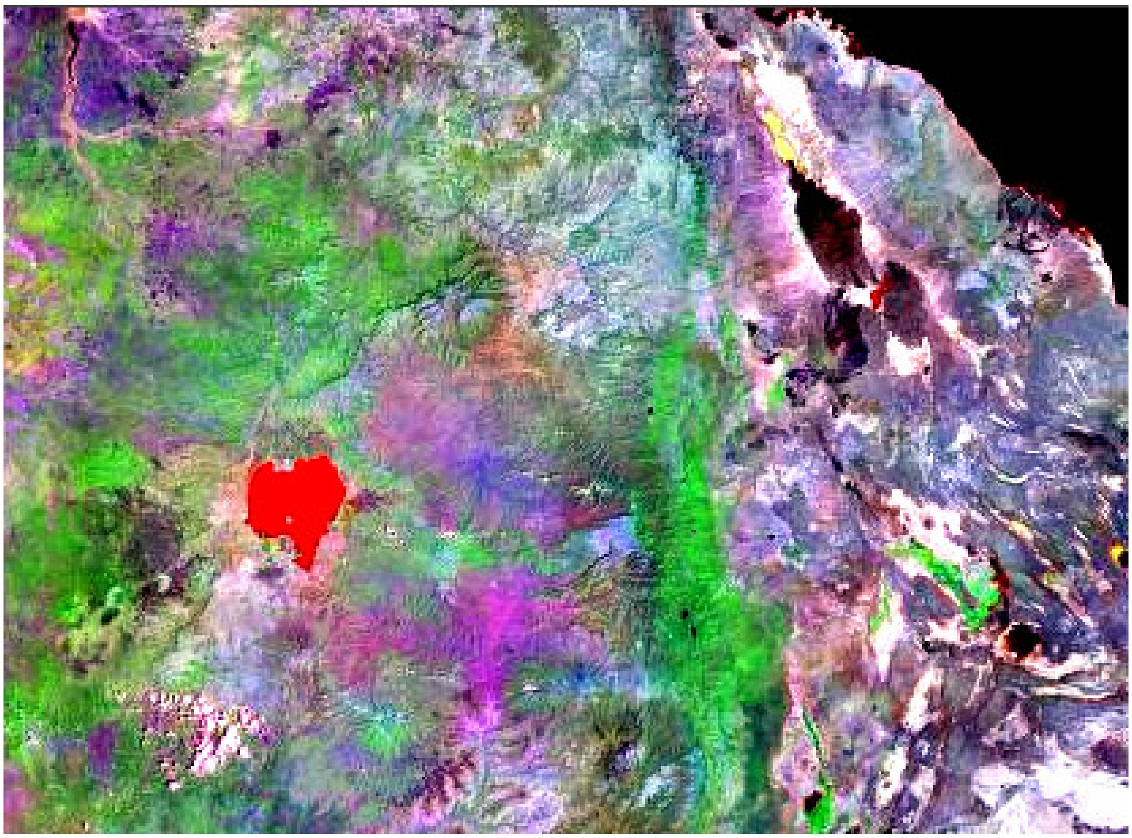
Appendix-3



Seismic hazard map of Europ-Africa-MiddleEast,from www.seism.etz,global seismic hazard assessment program.

Appendix-4

Satellite image that covers the northern part of Ethiopia, resolution 14.2by 14.2 meter, of land sat geocover200.



Declaration

I the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other university, and that all sources of material used for the Thesis have been duly acknowledged.

________________ _____________ _______

Name signature date

This Thesis has been submitted for examination with my approval as a university advisor.

________________ ______________ ________

Name signature date