Opportunities for Dimension stone resource development in Ethiopia

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# Table of Content

1. **Introduction** ......................................................................................................................... i  
   1.1 *Uses of Dimension stone* ........................................................................................................ 1
2. **Geology of Dimension stone in Ethiopia** .................................................................................. 5
3. **Dimension Stone Deposits in Ethiopia** .................................................................................... 8
   3.1 *Marble* ...................................................................................................................................... 8  
      3.1.1 Bapuri Marble ......................................................................................................................... 9  
      3.1.2 Mora marble ........................................................................................................................... 9  
      3.1.3 Bulen Marble .......................................................................................................................... 10  
      3.1.4 Ekonte Marble ......................................................................................................................... 11  
      3.1.5 Tulu Moye Marble ..................................................................................................................... 11  
      3.1.6 Mankush Marble ....................................................................................................................... 12  
      3.1.7 Daleti Marble .......................................................................................................................... 15  
      3.1.8 Naeder Marble ......................................................................................................................... 15  
      3.1.9 Dichenamo marble .................................................................................................................... 15  
      3.1.10 Newi Marble .......................................................................................................................... 16  
      3.1.11 Adiwoyane Marble ............................................................................................................... 16  
      3.1.12 Taget Marble ......................................................................................................................... 16  
      3.1.13 Emnizong Marble .................................................................................................................... 16  
      3.1.14 Akmara Marble ....................................................................................................................... 16  
      3.1.15 Endetukitr/Tekeze Marble ....................................................................................................... 17
   3.2 *Granite* ..................................................................................................................................... 18  
      3.2.1 Babile granite ........................................................................................................................... 19  
      3.2.2 Hamaresa ............................................................................................................................... 20  
      3.2.3 Bure and Angerguten Granites ............................................................................................... 21  
      3.2.4 Dehan granite .......................................................................................................................... 22  
      3.2.5 Negash granite ........................................................................................................................ 23  
      3.2.6 Adi Elena Granite ..................................................................................................................... 24  
      3.2.7 Adikelete Granite ..................................................................................................................... 24  
      3.2.8 Kedena Granite ......................................................................................................................... 24  
      3.2.9 Borpuah Granite ....................................................................................................................... 24  
      3.2.10 Kisad Gaba Granite .................................................................................................................. 24  
      3.2.11 Embamadr Granite .................................................................................................................. 25  
      3.2.12 Adiet Granite .......................................................................................................................... 25  
      3.2.13 Sebeya Granite ......................................................................................................................... 25
   3.3 *Slate* ......................................................................................................................................... 25  
      3.3.1 Gilgile Slate ............................................................................................................................. 27  
      3.3.2 Chiemite Slate ......................................................................................................................... 27  
      3.3.3 Guftamne Slate ......................................................................................................................... 27
   3.4 *Limestone* ............................................................................................................................... 28  
      3.4.1 Hakimgara .............................................................................................................................. 29  
      3.4.2 Delga Chebsi limestone ............................................................................................................ 30  
      3.4.3 Jema and Woonchit ............................................................................................................... 31  
      3.4.4 Dejen and Filikilik Limestone Deposits ................................................................................... 32
3.4.5 Mosobo limestone...................................................................................................................... 33
3.4.6 Sherafo Limestone ....................................................................................................................... 33
3.4.7 Neta’et (Ma’alagmal) Limestone................................................................................................ 34
3.5 Sandstone........................................................................................................................................... 34
  3.5.1 Ambo sandstone.......................................................................................................................... 34
3.6 Volcanic Rocks ................................................................................................................................... 35
  3.6.1 Ignimbrite..................................................................................................................................... 36
  3.6.2 Basalt.......................................................................................................................................... 37
4. Market................................................................................................................................................... 38
5. Opportunity ......................................................................................................................................... 40
6. Reference ............................................................................................................................................ 43
1. Introduction

The term dimension stone is defined as, “a natural building stone that has been selected, cut and trimmed to specified shapes or sizes with or without one or more mechanically dressed surfaces”. The definition applies to rough blocks, slabs and polished material used in building and construction and monument industries. Stones that are finished to specific dimension and shape are considered as dimension stone. It can be defined as natural rock material quarried for the purpose of obtaining blocks or slabs that meet specifications as to size and shape (Figure 1).

![Figure 1](image1.png)

*Figure 1 Cut and polished marble used for exterior and interior construction of buildings (National Mining Company, Awash Dimension Stone processing, Awash, Shoa, Central Ethiopia).*

Stone is one of nature’s own building material, undoubtedly the oldest construction material known to man (Heldal, 1997). Many of ancient civilization have contributed to stone architecture. The Axum Oblesque, Temple of Yeha, St, Gorge Church of Lalibela and the Fasiledes Palace of Gonder in Ethiopia, are perfect examples of ancient use of undressed stone popular to tourist (Figure 2).

![Figure 2](image2.png)

*Figure 2 Stone architecture showing ancient civilization a) Axum Oblesque b) St, Gorge Church of Lalibela and c) The Fasiledes Palace of Gonder (Photograph by Haileyesus Walle).*

Dimension stone, sometimes called ornamental stone for the basic reason that it gives a romantic beauty to the fascinating architects of modern buildings. Color, grain size, texture and pattern, and surface finish of the stone are normal requirements. Durability, strength, and the ability of the stone to take a polish are also other important selection criteria (Figure 3).
There are numerous geological features which a prospector needs to both recognize and record during the prospecting and early stage evaluation of a dimension stone site. These characteristics critically influence the long term marketability / commercial value of a specific dimension stone. These features includes the visual or aesthetic features which are color, grain size, and textures; and the technical features including petrography and mineralogy, brittle deformation, physical-mechanical properties, and available volumes. Consistent visual or aesthetic features are of prime importance when evaluating the market potential of a stone. The technical features influence the performance of a stone and the choice of stone for particular uses (i.e.: indoor, outdoor, intense sunlight exposure, pollution, exposure to chemicals, grease, oil etc.). Higher technical ratings led to increased acceptance for various uses in the marketplace.

Although a variety of igneous, metamorphic, and sedimentary rocks are used as dimension stone, the principal rock types are granite, limestone, marble, sandstone, and slate. Other varieties of dimension stone that are normally considered to be special minor types include alabaster (massive gypsum), soapstone (massive talc), serpentine, green stone and various products fashioned from natural stone (Figure 4).

The dimension stone industry is very much a world-wide industry, involving more than 50 major countries that are currently producing, exporting, and consuming stone products (i.e.: rough block, monument blank, polished slabs, tiles, and cut-to-size finished stones. Brazil, China, India, Italy, and Spain are the major producers of dimension stone, and each have annual production levels of nine to over twenty-two million tons. Portugal produces 3 million tons of dimension stone each year The United States of America is the world’s biggest consumer of dimension stone. http://www.nr.gov.nl.ca/mines&en/geosurvey/dimension/wkshop.pdf)

Using stone as a building material has long history in Ethiopia. The Obelisk of Axum, St. Gorge Churches of Lalibela and Temple
of Yeha were built by curved granite, ignimbrite and sandstone, respectively (Heldal and Walle, 2000; Asrat 2009) (Figure 5). Basalt cobbles/ rubbles, in central, slates and sandstone, in northern, have been used for construction of pavement and low cost houses.

![Figure 5 Historically unique heritage built by dimension stone: a) Rock-Hewn beautifully chiselled ignimbrite church of Lalibela. b) Yeha Temple, pre-Aksumite period, 8th – 4th century B.C. built by blocks of sandstone. b) Neatly fitting sandstone blocks of the ancient temple of Yeha. Source: (http://www.traveladventures.org/continents/africa/yeha02.shtml)

GSE has invited national and international companies to involve in exploration and quarry development. Accordingly, a number of international and local mining companies were granted exploration, and mining licenses to quarry marble, limestone and granite in the north, east and western parts of the country. Quarries in north and west produce large quantities of marble. Granite quarries in north, west and eastern parts of the country produce commercial blocks (2.4 x 1.2 x 1m, about 8 tones). Limestone quarry in Harar, in the east, and marble in the west, use diamond impregnated belt saws, to extract blocks. (Figure 6).

![Figure 6 Limestone quarry using diamond impregnated belt saws, Harar (Photo by Haileyesus Walle)]

Processing companies have stone fabricating plants at numerous locations, most of which are located away from the quarry sites. The National Mining Company (NMC) has quarries in the east and western part of the country, but the processing plant is located in Awash, Central Ethiopia.
1.1 Uses of Dimension stone

Dimension stone has been extensively used as exterior and interior applications, as slabs or massive works for flooring and wall tiles in public and commercial buildings and monuments (Figure 7).

Because of its abundance, basalt and granite were commonly used to build foundations. Polished marble and granite are also a popular choice for kitchen countertops due to its high durability and aesthetic qualities (Figure 8). In building and for countertops, the term "granite" is often applied to all igneous rocks with large crystals, and not specifically to those with a granitic composition (Stone, 2000).

Large volumes of stone are used in the construction industry. Polished slabs of 2 cm thick are used for the exterior facings of private and office buildings. Marble and granite can also be cut into floor tiles (30 cm by 30 cm) and countertops, and used in shopping malls, hotels, and even private homes. Granite curbing and cobblestone are used in pavement for cities because it lasts so long. Slate is cut into small square blocks and split into roofing shingles; in large sheets it can be used for pool table tops.

Limited use is made of steel framework which require careful fitting. ‘Architects’ drawing are usually consider sufficient, with attention to drafting and pattern-making where required. The main types of dimension stone are ashlar, slabby, rubble and trimming.
2. Geology of Dimension stone in Ethiopia

A wide variety of rocks are used as dimension stone in Ethiopia (Figure 6). The Precambrian metamorphic and igneous rocks comprise potential resources including marble and granite. These rocks are exposed in the east central (Harar), west central (Gojam and Wellega), north (Gondar and Tigray) and southern (Sidamo, Bale and Illibabore) parts of the country.

Most of the exposures are found in the peripheral regions, where younger rocks have been removed by erosion. Extensive deposits of marble occur in Kelafinos, Newi, Enda-Tikur, Naedir and Berdada (Tigray); Baruda, Mora, Daleti Ganzi Mankush and Bulen in Benishangul Gumuz Regional State (Figure 10 and 11).

**Figure 10 Dimension stone occurrences in Ethiopia**
A variety of igneous rocks, predominantly granites of Proterozoic to Early Palaeozoic age, occur as intrusive bodies within the Precambrian metamorphics. Some of these have been emplaced prior or simultaneous to tectonometamorphic events, others postdate these events (Tefera et al. 1986). Deposits of such types occur in Dehan and Angerguten in west, Babile in east, Meleka in south and north Negash in northern parts of the country (Figure 12).

Thick successions of Palaeozoic and Mesozoic sediments include building stone quality of limestone and sandstone. In the west-central part of the country, the lower part of the Mesozoic successions are represented by the Triassic to Jurassic Adigrat sandstone resting unconformably on the Precambrian basement, or slightly unconformable on locally developed Palaeozoic sediments (More, 1971). The Adigrat sandstone varies in thickness from few to 800 metres, and consists essentially of red to yellowish, well-sorted quartz sandstone (Figure 13).
The upper part, however, is in places calcareous, particularly close to the transition to the overlying limestone of the Antalo Group. Thick limestones are developed in the middle part of this group, varying from near-shore, oolitic limestones, through fossiliferous, pale limestone and marl to black limestone deposited in deeper water (Figure 14). In the Harar area, a possible correlative to the Antalo Limestone, the Hamanlei Series, exhibits thick beds of pale, calcitic to dolomitic limestone.

The Cenozoic volcanic rocks, Tertiary and Quaternary volcanic rocks cover a large part of the country (44%). These are associated with the formation of the Main Ethiopia Rift, Afar depression and the highland volcanics. The unit consists of basalts, trachytes and associated dyke swarms, andesites, rhyolites, ignimbrites and pumice. In these areas, the extensive plateau basalts and ignimbrites are extensively used for local housing and construction of roads (Heldal, Walle and Zewdie, 2000) (Figure 15 and 16).
3. Dimension Stone Deposits in Ethiopia

3.1 Marble

Marble is a crystalline, compact variety of metamorphosed limestone transformed through the heat and pressure into a dense, variously colored, crystallized rock. It is predominantly composed of calcite with minor impurities. Pure calcite is white in color. Iron and magnesium and some silicate minerals give a significant green color; graphite gives dark, pyrite greenish grey and hematite color marble pink. Some rare colors like sky-blue are due to impurities or “failure” within the calcite crystals (Heldal, and Wale, 2000 and Ministry of Mines 2002) (Figure 17).

Figure 17 Verities of color marble slabs a) Pink marble (Mankush); b) Grey marble (Mora); c) Sky-blue (Daleti); d) Black marble (Bulen)

Extensive deposits of marble are found in the Precambrian metamorphic terrain of northern and western Ethiopia (T. Heldal, H. Wale and S. Zewdie 1987; T. Heldal, H. Wale, 2000).

In the west, known deposit occur around Daleti, Bulen, Mora, Zigi, Baruda and Mankush. Most of the outcrops are hilly to cliff-forming, white to gray, coarse grained composed of dominantly calcite. Pink, greenish and sky-blue varieties and dolomitic marbles are locally present (Heldal, Wale and Zewdie 1987; Heldal, Wale, 2000) (Figure 18).

Figure 18 Out crop of white and coarse grained marble (Ganzi)

Marble deposit of northern Ethiopia is different from that of the west. Except the age, the grain size and color are different. It is fine grained with appearance closer to the originated limestone. These variations are accounted for the low degree of metamorphism. White, yellow and violet verities of colors are common. (Heldal, and Wale, 2000)

Marble is quarried for a variety of architectural and artistic purposes in Ethiopia. They are essentially small-scale operations, applying hand-held drill hammers and wedges as the primary tools, without using more sophisticated methods such as blasting and/or sawing. Wedging along vertical and horizontal drill-hole lines, helped by natural joints, makes primary cuts. Final shaping of blocks is made with secondary drilling and wedging. The maximum size of the final block is 1.15 ton,
limited by the loading capacity of the transporting trucks. Large, commercial blocks are extracted by means of drilling, blasting, wedging and diamond sawing (Figure 19).

![Figure 19 Diamond wire sawing for block extraction (Daleti marble)](image19)

### 3.1.1 Bapuri Marble

Bapuri marble deposit is found around Mora village, Zone, Benishangul Gumuz Regional, at the locality called Bapuri Metekel Zone Benishangul Gumuz Regional State; about 600 km west of Addis Ababa.

The marble is grey to white, coarse grained calcitic marble with calcite 85% and dolomite 5%. The physical and chemical properties indicate that the rock is suitable for both interior and exterior applications (Walle and Heldal 2001).

![Figure 20 Geological Map of Mora](image20)

### 3.1.2 Mora marble

Mora marble deposit is found around Mora village, Metekel Zone, Benishangul Gumuz Regional State; about 595 km west of Addis Ababa.

The marble occurs as strike parallel lenses, presumably reflecting fold patterns intercalated with amphibolites, quartzite and schists intruded by granitic, mafic and ultramafic intrusions (Figure 20) (Walle and Heldal 2001).

Ethiopian Marble Industry (EMI) quarry the marble extracting large, commercial blocks by means of drilling and wedging (Figure 21).
Currently Berta owns and opened pilot quarry extracting commercial blocks by means of drilling and wedging.

### 3.1.3 Bulen Marble

The deposit is located near Bulen town, some 580km west of Addis Ababa, in Metekel zone, Benishangul Gumuz Regional State.

The Bulen marble is associated with meta-granite, amphibolite and phylite (Figure 22). The marble is light grey to dark grey in color; fine to coarse grained, graphitic, composed of calcite 70% and graphite 25%. (Walle and Zewdie, 2000). The reserve is estimated up to $24.51 \times 10^6$ tons.

The deposit is relatively fractured near the contact with the surrounding Tertiary Basalt but there is a possibility of getting potential resource at the center (Figure 22).

The physical properties, especially the color, cut and polished testes indicate the marble can be used for external and external purposes as tiles and slabs. (Figure 23).
3.1.4 Ekonte Marble

The deposit located near the town Baruda, at the locality Ekonte; about 605 km west of Addis Ababa, in Metekel Zone, Benishangul-Gumuz Regional State.

The marble is white, light grey to grey, coarse grained calcitic (Figure 24). It is jointed and fractured with joint spacing capable of extracting potential blocks up to 16 tons and reserves about 4.98x10^6 tons.

At present small quarry operations are taken place by Ethiopian Marble Industry (EMI). Hand-held drill hammers and wedges are used to extract blocks. The blocks are transported to the processing plant in Addis Ababa.

3.1.5 Tulu Moye Marble

The deposit is located near the town Baruda, at the place called Tulu-Moye; about 610 km west of Addis Ababa, in Metekel Zone, Benishangul-Gumuz Regional State.

The Tulu Moye marble is hill forming, grey to black in color, fine grained, graphitic with 91% calcite. It is fractured and jointed with preferable joint spacing to extract blocks up to 32 tons.

Exploration indicates that opening quarry face on Tulu Moye marble is a bit difficult on the sides of vertical cliffs (Figure 25). However, if modern quarrying technology employed, it is easy to exploit the resource
3.1.6 Mankush Marble

Mankush marble is found in Mankush town, Metekel zone, Benishangul Gumuz Regional State, about 705 km west of Addis Ababa.

The marble deposits in this area belong to the medium grade, meta-sedimentary successions of the Precambrian Upper Complex. The marbles occur as strike parallel lenses (presumably reflecting fold patterns), intercalated with amphibolite, quartzite and schists. The metasedimentary rocks are intruded by granitic, mafic and ultramafic intrusions, which cover a large part of the area.

The calcite marble also occurs as blocks of variable sizes. The blocks commonly have smooth, rounded and elliptical surfaces. These blocks are at places partially covered. The less covered parts show clear arrangements of the blocks along the strike direction and joints are clearly observed that produced these blocks (Figure 26). The sizes of these blocks are directly proportional to the spacing of joints. Some part of the calcite marble contain variable amount of dolomite marble either as alternating unit or as veins and veinlets within the calcitic marble (Mohamed, Melkau and Tutan, 2009) (Figure 30).

The outcrop of the deposit is relatively flat lying, continuous to irregular body (Figure 15). It has variegated color ranging from white with grey veins, grey with white veins and localized pink verities and dominantly grey and thinly to wide dark bands. The dark bands are due to graphite. The pink, coarse grained, thin and long lenses are due to contacts with basic intrusions mostly occur at the peripheries of the deposit.

The physical and mineralogical analysis of Mankush marble fulfils the required properties of dimension stone.
Cut and polished properties of Mankush marble were determined on samples 10cm X 10cm X 2cm size. The result indicated that the marble is easily cut and polished with sharp edge, smooth with no pit (Figure 27). The polished surfaces especially the grey, banded and rose/pink varieties are attractive and beautiful.

The marble is tectonically disturbed with abundant syntectonic granitic, pegmatitic, granodioritic-dioritic intrusions and metavolcano-sedimentary lenses (Figure 28,29) (Said, 050-351-04). Parallel and crosscutting dykes and veins of amphibolite and granite are common. There are two dominant joint systems with joint spacing up to 3m.

Ethio-Marble Industry (EMI) and Berta Construction have owned part of the resources and started pilot quarry to extract blocks. Blocks are extracted using pneumatic hand drill hammer, wedges and jack. Extracted squared blocks loaded on tracks and transported to processing plant in Addis Ababa (Figure 29).
Figure 30 Geological map of Mankush marble (After Mohamed et al., 2009)
3.1.7 Daleti Marble

The deposit is named after the town Daleti, found in Benishangul Gumuz Regional State, about 635 km west of Addis Ababa. The marble is one of the known deposits which have been exploited for a long period of time. The deposit is flat to hill forming, generally exhibits variety of colors ranging in white, dark-gray, gray, pink, blue and green patches (Multicolor) (Figure 31).

The “multicolor”, blue and pink varieties are rare. The pink, silicate rich marble and sky blue marble occur around the contact zones with basic dykes. Like the color, there are also different grain sizes. Coarse-grained white marble with minor graphitic bands, coarse-grained graphitic marble with white bands and white fine-grained with green to grey patches; fine to medium grained white marble are some of the varieties. The marbles are calcitic, with minor amounts of dolomite, graphite, quartz and phyllosilicates. Quartz is usually present as nearly horizontal veins and as scattered aggregates (Walle and Heldal, 2001).

The National Mining Company (NMC) operates several quarries on the Daleti marble.

The extraction techniques are highly sophisticated, where both cutting by diamond wire and water-jet technology are applied (Figure 32).

3.1.8 Naeder Marble

The Naeder marble is situated in Naeder-Adet Wereda, in the central zone of Tigray. It is bounded between 13°46’ N 13°54’N latitudes and 38°45’ and 39°00E longitudes. The deposit is situated about 55 Km from Axum (Figure 34). The marble body is predominantly black to dark gray, fine grained and compact. The average block size is 2m X 2.2m X 1.7m. The total reserve is calculated and estimated to be 8.23X108 m3 (Tigray Region Bureau Water, Mineral and Energy, 2006)

3.1.9 Dichenamo marble

The deposit occurs in western Tigray, 30 km from Shiraro (Figure 34). The marble is fine- to medium-grained, and appears in several colour varieties, such as grey, purple, multi-colour, rose and green (Figure 33).
The deposit is owned by Saba Stone processing Factory (Walle and Heldal, 2001). In the quarry, diamond wire sawing is used for primary extraction of blocks.

3.1.10 Newi Marble

Newi Marble deposit is found in Kola Tembien wereda in the central zone of Tigray about 42 Km north-west of Abi Adi town. It can be reached through Abi Adi-Newi dry weather road (Figure 34). The deposit is bounded between 13°46' to 13°54’N latitudes and 38°30-38°45’E longitudes.

The rock is Predominately black to dark gray, compacted, fine grained and jointed with average block size 3.3m X 2.3mx1.3. The estimated reserve of the deposit is 14.72 x 10^6 (Tigray Region Bureau Water, Mineral and Energy, 2006).

3.1.11 Adiwoyane Marble

The deposit is located in Kola Tembien Wereda in the central zone of Tigray at the locality called Adiwoyane, 13km SW of Abi Adi. The area is bounded between 1 3°31’N-1 3°34’N latitude and 38°56’E-38°59’ longitudes. The deposit can be reached Adi-Adiwoyane dry weather road (Figure 34). The marble is dominantly dark gray to black, fine grained compact, jointed with average block size 1.3m X 1.8m X 2.4m. The estimated reserve is calculated to be 6.87 X 105m3 (Tigray Region Bureau Water, Mineral and Energy, 2006)

3.1.12 Taget Marble

Taget marble is found in Kola Tembjen Wereda in the central zone of Tigray, 8km south west of Abi Adi, on the road to Tashmane village (Figure 34). The marble is dark gray to black, fine grained, compacted and jointed with average block size 2.4m X 2.6m and 1 .75 X 2.9m with available third dimension.

3.1.13 Emnizong Marble

The deposit is found in Medebay-Zana Woreda, in the North western zone of Tigray. It is located about 60km south of Axum. The target area is roughly centered at 13°52N latitude and 38a33E longitude (Figure 34). The marble t is snow white, fine-grained and compacted. The exploitable reserve is limited to an area of 288.850m² (Tigray Region Bureau Water, Mineral and Energy, 2006).

3.1.14 Akmara Marble

The resource is found in kola Tembien Woreda in the Central zone of Tigrai, about 44km North West of Abi Adi. The area is bounded between 13°41’13” to 13°45’00” N latitudes and 38°42’47” 38°45’00”6 E longitudes. The area can be
reached using the Abi Adi-Newi-Akmara dry weather road (Figure 34).

The marble is smoky white to white, dark gray to gray, fine to medium grained and compact.
It has appreciable blocks of commercial sizes with reserve estimated 543x106 meter cube Tigray Region Bureau Water, Mineral and Energy, 2006).

3.1.15 Endetukrir/Tekeze Marble

This marble deposit is found in western Tigray, in the Adi Aseri village, 52 km southwest of Shiraro and about 153 km south west of Endaslassie town. It is bounded between 14°2’00” N to 14°12’N latitude and 37°35’22” to 37°45’E longitude. The area can be reached by Endasilassje -Tekeze -Flumera all weather road (Figure 34).

The geological setting indicates that the marble occurs as a 13 km long horizon from the Tekeze River in the south to the Adi Asser village in the north, striking N25°E. Utcrops are found in the Tekeze Gorge and on a ridge extending towards Wolkaite area. The marble is enveloped by chlorite schist intercalated with slate and mica schist. Along the contacts, the marble is foliated and not of any commercial value (Walle and Heldal, 2001).

The marble is light yellow with some smoky white and multi color out crops, medium grained crystalline, and compact. Physical weathering and chemical dissolution affect the upper part of the marble deposit. Large blocks can be exploited along streambeds and towards the more massive centre of the deposit. The reserve of the deposit is estimated to be 193.76 m3 with blocks of commercial size up to 1 x 0.8 x 1.5m Tigray Region Bureau Water, Mineral and Energy, 2006).

Figure 34 Geological map and marble deposit of part of Northern Ethiopia (Source of deposit Tigray Region Bureau Water, Mineral and Energy, 2006).
3.2 Granite

Granite is a common and widely occurring type of intrusive, felsic, igneous rock. The word granite comes from the Latin *granum*, a grain, in reference to the coarse-grained structure of such a crystalline rock.

“Granite” is a term, which, for geologists, defines a plutonic rock of a specific composition, containing plagioclase, orthoclase and quartz as the main minerals. However, in the dimension-stone trade, the term is applied for a wide range of hard, siliceous rocks, including closely related plutonic rocks such as granodiorite and tonalite, less related plutonic rocks e.g. gabbro and monzonite, and even some metamorphic rocks, such as gneiss (Walle and Heldal, 2001). Granites usually have a medium to coarse grained texture. Occasionally some individual crystals (phenocrysts) are larger than the groundmass in which case the texture is known as porphyritic. A granitic rock with a porphyritic texture is sometimes known as porphyry. Granites can be pink to gray in color, depending on their chemistry and mineralogy (Figure 35).

Outcrops of granite tend to form tors (outcrops formed by weathering), and rounded massifs. Granites sometimes occur in circular depressions surrounded by a range of hills, formed by the metamorphic aureole or hornfels. Granite is found in the continental plates of the Earth’s Crust.

Granite is nearly always massive (lacking internal structures), hard and tough, and therefore it has gained widespread use as a construction stone (Figure 36). The average density of granite is located between 2.65 and 2.75 g/cm³, its compressive strength usually lies above 200 MPa and its viscosity at standard temperature and pressure is $3-6 \cdot 10^{19}$ Pa·s.

Granite is currently known only on Earth where it forms a major part of continental crust. Granite often occurs as relatively small, less than 100 km² stock masses (stocks) and in batholiths that are often associated with orogenic mountain ranges. Small dikes of granitic composition called aplites are often associated with the margins of granitic intrusions. In some locations very coarse-grained pegmatite masses occur with granite.
Granite has been intruded into the crust of the Earth during all geologic periods, although much of it is of Precambrian age. Granitic rock is widely distributed throughout the continental crust of the Earth and is the most abundant basement rock that underlies the relatively thin sedimentary veneer of the continents.

Granite has different applications as dimension stone such as granite curbing, cobblestones, and granite pavers, landscaping stones, granite slabs, granite steps, granite, monuments, gravestone, millstones and other building products.

The commercial quality of granite deposits depends on several factors in addition to its appearance on polished surfaces, e.g. colour and texture. Homogeneity is considered to be an important factor when trading dimension-stone (Figure 37). The deposits should not contain high amounts of veins and dykes, and inclusions such as xenoliths.

Pre- and syntectonic granitoids within the Middle and Upper Complexes comprise medium-grained, grey granodiorites, fine-grained, pink to red granite, coarse-grained, pink granite and porphyritic, pink to grey granites. The plutons may show a penetrative foliation throughout their entire thickness, or have a foliated margin with a massive, non-foliated core (Figure 38).

**3.2.1 Babile granite**

The Babile granite is found near Babile town about 34 km east of Harar. Access is possible through Harar-Jijiga asphalt road.

The Babile granite is medium grained, pink to red with dark patches; and has a variegated, veined structure, reflecting its close relation to the surrounding migmatitic gneisses. The granite body vary from massive to strongly banded structure (Heldal, et al. 1997). The deposit constitutes massive boulders and smaller hills which give good opportunity for the extraction of commercial size blocks (Figure 39).
Currently, the deposit is exploited by NMC. Quarry operations are done using hand drill hammer and small explosive charges to split blocks (Figure 40, 41).

Final shaping of blocks is made with secondary drilling and wedging. Blocks are loaded on tracks and transported to the processing plant in Awash (Figure 42). The potential for locating new granite deposits is large and most of the deposit is located near by Harar-Jijiga main road.

3.2.2 Hamaresa

The granite deposit is found in the Hamaresa area, about 5 km from Harar on the way to Diredawa, around the localities called Hasenge and Sukul. It is accessible using Harar Diredawa asphalt road.

The granite is boulder type, gray to pink, coarse grained composed of mainly quartz, feldspar and biotite. At places, the granite is weathered to an average depth of two metres (Walle and Heldal, 2001). On the outcrop the average height of the boulders reach up to 15 m (Figure 43 ). There are three sets of joints capable to produce commercial size blocks.
Pilot mining was carried out by Ethiolibian Mining Company (ELMICO). Leftover blocks in the quarry indicate that the content of biotite-rich inclusions (xenoliths) in the deposit is high, thus reducing the commercial value of the deposit (Walle and Heldal, 2001). The resources of Hamaresa granite reaches 1.5 mill. m³ in Hasenge and 0.4 mill. m³ in Sukul areas (Walle and Heldal, 2001).

Figure 43 Blocks and boulders of granite on top of weathered surface. Photograph by Sentayehu Zewdie

3.2.3 Bure and Angerguten Granites

The deposit occurs in western part of the country, extending from Angerguten in Welega to Bure in Gojam (Bekotabo).

The granites and granodiorites in the area occur as several intrusive bodies within the Precambrian metasedimentary and metavolcanic successions. They are deformed and show a metamorphic foliation trending N30°E, dipping gently to subvertical. The granites commonly form hills with prominent cliffs. The deposit forms smooth hills with a steep foliation. The granite is pink to grey, medium- to coarse-grained, and porphyritic with megacrysts of feldspars.

Granite boulders are common in the outcrop areas, on hills and along stream valleys. The possibility of extracting commercial size blocks from boulders and the solid rock beneath seem good. Compared to the Dehan and Babile granites, the biotite content is high, thus leading to a darker appearance on polished slabs.

The granite is foliated/porphyritic with large, pink phenocrysts of microcline in a brownish grey groundmass of biotite, plagioclase and quartz. K-feldspar dominates in composition compared to the other minerals. The phenocrysts are evenly distributed within the biotite-rich groundmass, and measure 3-5 cm in size (Figure 44).

Figure 44 Polished slabs showing augns of feldspar with biotite reach (Angerguten Granite).

The mineralogical analysis indicates the granite composed of 55% K-feldspar, 25% quartz, 9% plagioclase, 5% biotite and 5% muscovite. The granite has also bulk density 2.67, porosity 1.262 %, water absorption 0.474%, and compressive strength 753 kg/cm².
Currently NMC has pilot quarry in Angerguten and produce blocks using hand drill hammer and explosive. The blocks are transported to the processing plant in Awash. Most of the finished slabs have local market and are used as table top in most of commercial buildings such as banks and hotels (Figure 45).

Figure 45 Blocks of Angerguten Granites ready for transport. Photograph by Haileyesus Wale.

Both the Bure and Angerguten granite have huge resources, good quality and accessible and can be recommended for large scale quarry activities.

3.2.4 Dehan granite

The Dehan granite is found around Mora, Metekel Zone in Benishangul-Gumuz Regional State. The granite is pink with greenish spots, and forms large hills and ridges in the area between Mora and Galesa.

It is coarse-grained, slightly foliated and seems homogeneous in colour and texture. Easily extractable, large boulders are common in the area (Figure 46)

Figure 46 Rounded, massive and big block of granite (Dehan Granite)

Rarely, biotite-rich inclusions occur in the peripheral, and are slightly more fine-grained in the central part. Locally, the granite is weathered and more fractured.

The mineralogical analysis indicates the granite composed of 27% K-feldspar, 30% quartz, 20% plagioclase, 9% biotite, 5% sericite, 6% epidote and Chlorite 3%.

The granite has also bulk density 2.7, bulk density 2.7, porosity 1.2%, water absorption 0.4%, and compressive strength 1253 kg/cm².

The reserve of the granite is estimated to 7 mill. tons and has good potential for extraction of large, homogenous blocks (Figure 47).
Compared to many other granite deposits in Ethiopia, the Dehan granite seems to have a uniform, pink colour with low content of mafic minerals. The sizes of the boulders (up to 50m3) indicate potential for large blocks.

### 3.2.5 Negash granite

The deposit is located in eastern Tigray, 55km from Mekele town in Negash Woreda on the Mekele - Adigrat asphalt road.

The granite body is found between the coordinates 39° 36’ 3”- 39° 36’ 37” E and 13° 53’ 30”- 13° 54’ 49”N

The Negash granite occurs within the Late Proterozoic metasedimentary and metavolcanic rocks. These are overlain by thick piles of Mesozoic sedimentary rocks. Several bodies of syn- and post-tectonic, granitic and basic igneous rocks intrude the basement rocks. The youngest rocks in the area are the Tertiary volcanic rocks, which cover both the basement and the Mesozoic rocks (Walle and Heldal, 2001).

The granite is well exposed, and forms a N-S oriented ridge (Figure 48). The rock is medium-grained, pink to light brown in colour, composed of quartz (35%), microcline (33%), plagioclase (27%), and muscovite (5%). It has bulk density 2.623, porosity 1.14 and water absorption 0.44%. The reserve is estimated to be 58,012,500m3 (Tigray Region Bureau Water, Mineral and Energy, 2006)

The low mica and higher K-feldspar makes the Negash granite preferable as good dimension stone. For this reason National Mining Company (NMC) had opened pilot quarry in the southeastern part of the deposit (Figure 49). Currently the NMC has abandoned the quarry due to unknown reason. However, there is still good opportunity to reopen the old quarry or open a new one.
3.2.6 Adi Elena Granite

The granite is located in western Tigray, about 55km from Axum. It is found at the coordinates 14°15’N latitude and 38°41’E longitude. The area can be reached through 15km dry weather road that connects Chila with the deposit.

The granite is light gray to black, medium grained, massive with wide space joints capable of producing blocks of the following size: 7m x 2.3m x 1.5m, 3.3m x 2.7m x 5m, 1.2m x 1.9m x 3.4m and 2.8m x 2.1m x 1.4m. Reserve is estimated to be 3.15 x 10m³ (Tigray Region Bureau Water, Mineral and Energy, 2006)

3.2.7 Adikelete Granite

Adikelete granite is found in western Tigray, in Lealay Adiabo woreda, about 68km from Endaselassie in the north western zone of Tigrai. It is situated between 15°30’ - 15°35’ N latitudes and 38° 15 ‘42” - 38° 13 ‘00” E longitude.

Access road to the Adi-kelete granite is through the Adinebried-dikelete dry weather road that branches off north wards at Adi-

3.2.8 Kedena Granite

The granite is found in western Tigray, about 47km from Axum about 8km NE of Chila in the central zone. The target area is centered at 14°19’N latitude and 38°39’E longitude.

The granite gray, medium grained massive, with wide spaced joints capable of producing blocks of the following size: 1.47mx 4m x4m, 2.67mx 4mx4m, 3mx3.7mx5m and 2mx5mx1.7m. Reserve is estimated to be 5.7x108m³ (Tigray Region Bureau Water, Mineral and Energy, 2006)

3.2.9 Borpuah Granite

The deposit is found in western Tigray, about 16km far from Rama, in the central zone of Tigray. It is accessible by dry weather road that connects with Rama town. The area is centered at 14°23’ latitude and 38°40’E longitude.

The granite is light gray, medium grained massive with joints capable of producing blocks of the following dimension: 4m X 2m X 1m, 4rn X 3m X 3.3m and 2m X 4rn X4.5m. Its reserve is estimated to be 4.6 x10⁷ m³ (Tigray Region Bureau Water, Mineral and Energy, 2006)

3.2.10 Kisad Gaba Granite

The Kisad Gaba Granite is found in Asgede-Tsimbla  woreda in the north western zone
of Tigrai. The granite body is located at about 37km south west of Endaselassie. It is bounded between 14°05’- 14°12’N latitude and 38°03-38°13’E longitude.

The granite outcrop is easily accessible by the Endaselassie - Kisad Gaba all weather road. It is pink to grayish pink, coarse to medium grained massive with joints capable of extracting blocks of the following dimension: 2m x 4mx 3m (Pink granite), 4.5m x 5m x 3m (gray granite).

3.2.11 Embamadr Granite

Embamadr Granite is situated about 3.3 km away from Embamadre-Maitsebri main road, in the north western zone of Tigrai. It is centered at 13°42’N latitude and 38°35’E longitude. It can be reached through the Endaselassie Embamadre Maitsebri all weather road.

The granite is pinkish, coarse grained, massive, compositionally homogenous with blocks of 2.5m x 3m x 5m, 4m x4m x 7m and 5m x 2.5m x 3.8m. The coverage of outcrop is estimated to be 13.2x10’m².

3.2.12 Adiet Granite

Adiet granite is located about 4km south of Edga solus in the central zone of Tigrai. It is centered at 13°48’N latitude and 38°27‘15”E longitude.

The rock is light pink, medium to coarse grained massive and jointed with joint space capable of producing different color block size. The block sizes of the pink granite are: 2m x 2.6m x 3.7m, 2m x 1.8m x 2.5m and 2m x 2.7m x 2.3m. The light pink variety has block sizes of: 7.2m x 6.3m x 2.4m, 4.5rn x 5m x 3.2m, 1.1 m x 2.1m x 1.8m, 1m x 2.6rn x 3.8rn, 1.8m x 3.7m x 1.9m and 3.1m x 4.7rn x 1.4rn.

The reserves are estimated for both varieties and found to be 1.359 x 10⁷ m3 and 9.27 x 10⁷ m³ for pink and light pink respectively (Tigray Region Bureau Water, Mineral and Energy, 2006)

3.2.13 Sebeya Granite

Sebeya granite is situated 15km east of zalambesa in the Eastern zone of Tigray. The granite body is centered at 14°28’N latitude and 39°31 ‘E longitude. The target area can be easily reached through the Zalambesa-Sebeya all weather road.

The granite is pink in color, medium grained and massive (Figure 50).

Figure 50  Pink polished Sebeya Granite

3.3 Slate

Slate is a fine-grained, foliated, homogeneous metamorphic rock derived from an original shale-type sedimentary
rock composed of clay or volcanic ash through low-grade regional metamorphism.

The word "slate" is also used for some objects made from slate. It may mean a single roofing slate, or a writing slate, traditionally a small piece of slate, often framed in wood, used with chalk as a notepad or noticeboard etc., and especially for recording charges in pubs and inns. The phrase "clean slate" or "blank slate" comes from this use.

When expertly "cut" by striking with a specialized tool in the quarry, many slates will form smooth flat sheets of stone which have long been used for roofing and floor tiles and other purposes. Slate is frequently grey in color, especially when seen in masse covering roofs. However, slate occurs in a variety of colors even from a single locality; ranging from many shades of grey, pale to dark, and may also be purple, green or cyan. Ninety percent of Europe's natural slate used for roofing originates from Spain.

Slate is mainly composed of quartz and muscovite or illite, often along with biotite, chlorite, hematite, and pyrite and, less frequently, apatite, graphite, kaolin, magnetite, tourmaline, or zircon as well as feldspar..

Slate can be made into roofing slates, also called roofing shingles, installed by a slater. Slate has two lines of breakability: cleavage and grain, which make it possible to split the stone into thin sheets. When broken, slate retains a natural appearance while remaining relatively flat and easily stackable.

Slate is particularly suitable as a roofing material as it has an extremely low water absorption index of less than 0.4% (Figure 51). Its low tendency to absorb water also makes it very resistant to frost damage and breakage due to freezing.

Slate roof tiles are usually fixed using either nail fixing, or the hook fixing method. Both these methods, if used properly, will provide a long-lasting weathertight roof with a typical lifespan of around 80–100 years.

Figure 51 Slate roofing and cladding

Slate tiles are often used for interior and exterior flooring, stairs, walkways, gravestone and wall cladding (Figure 52).

Figure 52 Slate gravestone
slate-producing regions in Europe include Wales in the United Kingdom; parts of France, Belgium; Liguria in northern Italy, Portugal, Germany’s Alta, Norway and Galicia. China has vast slate deposits; in recent years its export of finished and unfinished slate has increased, it has slate in various colors.

Slate is abundant in Brazil (the second-biggest producer of slate). Other areas known for slate production are the east coast of Newfoundland, the Slate Belt of Eastern Pennsylavnia, Buckingham County Virginia (Buckingham Slate), and the Slate Valley of Vermont and New York, where colored slate is mined in the Granville, New York area.

In Ethiopia, slate occurrences are reported only in the northern part of the country, Tigray Regional State in the meta-volcano sedimentary rocks. According to the Tigray mines office, there are several slate occurrences particularly around East of Adigrat, West of Hawzein and south of Abi-Adi. Slate is extensively used by the local people for roofing and wall constructions.

### 3.3.1 Gilgile Slate

Gilgile Slate is located about 10 km east of Adigrat in the eastern zone of Tigray. The deposit is approximately centred at 39°27′45″E longitude and 14°16′30″N latitude. It is accessible through the Mekelle-Adigrat main asphalt road.

The slate deposit forms a continuous ridge from Mayawlie towards Jilajile. It is overlain by the Adigrat sandstone (west) and underline by dolomite (east). The deposit covers an extensive area of about 700 m by 2 km. The slab thickness, spacing of the cleavage varies from less than a centimetre up to 10 cm, and the surface of the slab is quite irregular. Relatively wide spacing of joints allows slab sizes of about 1.5 m by 2.1 m. The unit strike N10°E, dipping 45°NW. The Slate is greenish blue, fine grained and compacted with individual cleavage thickness up to 3 mm to 1 cm and possible slab size 2 m x 2 m (Figure 53) (Tigray Region Bureau Water, Mineral and Energy, 2006).

![Figure 53 Gilgile Slate outcrop](image)

### 3.3.2 Chiemite Slate

The Chiemite Slate is found about 25 km north west of Hawzein in the eastern zone of Tigray. It is approximately centered at 39° 13′E longitude and 14°06N latitude.

It can be reached through Nebelet with Edaga Arbi all-weather road.

The slate is blue-black, fine grained and compacted with individual cleavage thickness about 3 mm to 1 cm and possible slab size up to 2 m x 1.5 m. The slate covers approximately 880,000 m² aerial coverage (Tigray Region Bureau Water, Mineral and Energy, 2006).

### 3.3.3 Guftamne Slate

Guftamne slate is situated in central zone of Tigray about 54 km south of Abi Adi. It is approximately centered at 38°50′E longitude and 13°16′N latitude. The area can be reached through Shewate...
Hugum Tekeze hydro power plant motorable road that branches off west Wards at Shewate Haghum from the Abi Adi Sokota all weather road. The slate is reddish brown and fine grained with individual cleavage thickness of 3 mm to and possible slab size 2m x 2m (Tigray Region Bureau Water, Mineral and Energy, 2006)

3.4 Limestone

Limestone rocks are sedimentary rocks that are made from the mineral calcite deposited from of evaporated seas and lakes and from sea animal shells. Sometimes it is almost pure calcite, but most limestones are filled with lots of other minerals and sand and they are called dirty limestones. The various minerals that make up a limestone rock affect its colors and shadings. Limestones are available in colors such as blue, shades of pink, yellow, brown, gray and red.

Limestone was most popular in the late 19th and early 20th centuries. It was also a very popular building block in the Middle ages in the areas where it occurred since it is hard, is durable, and commonly occurs in easily accessible surface exposures (Figure 54).

Many medieval churches and castles in Europe are made of limestone.

Limestone was, for a long time, the only building material available, and is still very frequently used on all types of buildings and sculptures (Figure 55). Limestone is readily available and relatively easy to cut into blocks or more elaborate carving. It is also long-lasting and stands up well to exposure.

Calcitic limestone of dimension-stone quality is predominantly found within the Jurassic Antalo limestone and the Hamanlei Series of Ethiopia (Walle and Heldal, 2001). The best exposures and the most interesting deposits of the Antalo Limestone are found in the central part of the Abay Valley and side valleys of Jema, Wonchit and Muger. Hakimgara, Jema, Dejen and Mosobo are some of the deposits which contain dimension stone quality of limestone. Currently the Hakimgara deposit is one of

Figure 54 The Great Pyramid of Giza, one of the Seven Wonders of the Ancient World, is made entirely from limestone. source: http://en.wikipedia.org/.

Figure 55 Hakimgara Limestone used as stairs in one of government building in Addis Ababa (Geological Survey of Ethiopian), Photograph by Sentayehu Zewdie
the active quarry in the country. This quarry is operated by EMI and MNC (Figure 56).

![Figure 56 Limestone quarry used diamond wire for extraction of blocks (NMC Quarry at Hakimgaras).](image)

### 3.4.1 Hakimgara

The Hakimkara limestone deposit is found in Harar town, Hakimgara area, 525km from Addis Ababa. The area is accessible through dry weather road connecting the town Harar to the deposit. The deposit is approximately centred at 42°07’E longitude and 09°16’N latitude. The limestone is creamy to yellowish in color with dark grey, large and small spots bedded and jointed (Figure 57. The horizontal beds vary in thickness, where the thicker beds are considered to be of best quality as dimension stone.

![Figure 57 Horizontal, yellow and creamy, thick and massive limestone bed (Hakimgara). Phot by Sentayehu Zewdie](image)

The limestone is calcitic in composition with low content of silica. It appears homogeneous, with the exception of the dark grey spots (Figure 58).

![Figure 58 Massive limestone bed with dark grey spots Photograph by Sentayehu Zewdie](image)

Two major sets of vertical and one horizontal joints are seen in the deposit. The horizontal joint is parallel with the bedding plan and the vertical ones are widely spaced and perpendicular to each other. Both the joints are capable of facilitating the extraction of squared blocks (figure 59).

![Figure 59 Massive and jointed limestone good for extraction of blocks (Hakimgara).](image)

Limestone blocks as dimension stone have been exploited for a long time in this area, and at present quarries are operated by the National Mining Corporation (NMC) and
Ethio Marble Industry (EMI) companies and local miners (Figure 60).

The possibility of obtaining large-sized blocks is considered to be good in the area, and the potential for future deposits seems satisfactory. At present time, the Hakimgara deposit is the only limestone deposit in Ethiopia subject to industrial scaled dimension stone production.

It is crushed for use as wall tiles, cobblestone and as aggregate of the solid base for many roads (Figure 61, 62).
The colour varies from yellow to grey, red or pink, fine-grained and fossiliferous (Figure 64). The bedding dips gently 20°-35° towards south.

![Image](image1)

Figure 64 Red Habbis limestone, Harar (NMC). Source: Geological Muesum (GSE).

The deposit is influenced by two fault systems striking E-W to WNW-ESE and NE-SW respectively. Three sets of joints are common (Figure 65).

![Image](image2)

Figure 65 Out crop of limestone, dipping sub-horizontal fractured and faulted

The content of quartz in the limestone varies, and there are gradual transitions from limestone to calcareous sandstone within the deposit. Clearly, cutting and polishing properties vary according to the quartz content. The there occur narrow spacing of joints, but there is also a possibility of getting wide spaced joints for dimension stone production.

### 3.4.3 Jema and Wonchit

The Jema and Wonchit limestone deposits are located in Northern Shoa, Merhabete District around Jema and Wonchit area.

The Jema and Wonchit area is one of the few places, within the central Ethiopian plateau, where outcrop areas of Mesozoic limestones actually occur (Mamo, et al. 1993). In these valleys, the limestone is overlain by Jurassic to Cretaceous shale and gypsum, Cretaceous to Tertiary sandstone and (on top) Tertiary volcanic rocks.

It forms steep cliffs within the river canyons. The near horizontal beds vary significantly in thickness, where the thickest and dimension stone quality occur in the lower part of the deposit (Figure 66).

![Image](image3)

Figure 66 Cliff of Jema limestone containing massive layers with intercalations of marl and shale

The limestone is light-yellow and creamy colour bedded, massive, microcrystalline
and fossiliferous. The individual layer ranges in thickness from 1.2 to 8 meters. The layers are jointed and commonly highly fractured. It is interbedded with thin layers of marl and shale.

There are sets of joints commonly occur, one parallel to bedding and two vertical. In a highly fractured part of the deposit, the maximum block size is 0.5-1m$^3$. However, there are still better block sizes in less fractured parts (Figure 67).

![Figure 67 Fracture and massive blocks of limestone (Jena).](image)

There is also good opportunity for the investors to involve with extraction of dimension stone blocks parallel with limestone for cement raw material in the region.

### 3.4.4 Dejen and Filikilik Limestone Deposits

The deposit is found in Gojam and Shoa, Abay Gorge between Dejen and Goha Tsion, around the localities Gelgel and Filikilik. The deposit is situated on the two opposite sides of the Abay canyon, on the road Addis Ababa to Debremarkos. Gelgel and Filikilik are the two localities where the deposit situated about 215 and 195 km from Addis, respectively.

The limestone is approximately 400 metres thick, and occurs between the Upper Shale and the Trap Series basalt (Figure 68). It is horizontally bedded, and in the lower part, intercalated with shale and marl. The limestone is predominantly fossiliferous. Bed thickness increases upwards to 0.5-2m at the uppermost part. The colour of the limestone varies from light yellow to grey and brownish grey.

![Figure 68 Outcrops of blocky limestone good for dimension stone](image)

Three sets of joints commonly occur - one along the bedding, and two steep sets, NW-SE and NE-SW trending, respectively. Commonly, thin layers of soft, weathered material, composed of quartz, illite, kaolin, dolomite and montmorillonite occur on the bed surfaces (Walle and Heldal, 2001). Steep cliffs and rock fall along them are common in the area.

The resource is potentially high in which some the upper part of the deposit exhibits relative thick and massive beds capable of extracting commercial size blocks (Figure 69).
3.4.5 Mosobo limestone

The deposit is found in Tigray, near Mekele town at the place called Mosobo. It is accessible on the Mekele Adigrat road. The area covers about 150,000m$^2$.

The limestone is white to yellow, crystalline and fossiliferous. The horizontally bedded limestone is extensively fractured, deeply weathered with three sets of joints, N20$^\circ$ E and N 70$^\circ$ W (Figure 70). Two major fault systems are present in the area, striking (Walle and Heldal, 2001).

3.4.6 Shcrafo Limestone

Shcrafo Limestone located about 3 km west of Agutat town located, on the Mekelle Adigrat asphalt road, in the eastern zone of Tigrai. The deposit is accessible by the dry weather road passing through Agula to Giza.

The limestone is grayish white in color, well bedded, massive and compacted with getting fresh layer at the bottom which fulfils the quality of the dimension stone (Figure 71, 72).
joint spacing capable of producing block sizes: 4m x 2m x 1.5m, 3m x 2m x 0.5m and 4m x 3m x 1m. The reserve is estimated to be 180,000 m$^3$ (Tigray Region Bureau Water, Mineral and Energy, 2006)

### 3.4.7 Neta’et (Ma’alagmal) Limestone

The deposit is found about 2.5 km west of Mekelle-Agula’e main asphalt road. The area is accessible by four wheel drive through the Mtkelle Agulae main road. The limestone is cliff forming yellow to gray yellow in color finely crystalline with joints capable of producing block sizes of 3m x 2m x 2m and 3m x 3m x 0.75m. The reserve is estimated to be 445,300 m$^3$ (Tigray Region Bureau Water, Mineral and Energy, 2006).

### 3.4.8 Gogon Da’ero limestone

The Gogon Da’ero limestone occur about 60 km east of the Mekelle Mairnekden asphalt road. The limestone is gray to black, massive, compacted and well bedded with joint spacing capable of producing block size of 3m x 2m x 1 m and 4m x 3m x 1m (Tigray Region Bureau Water, Mineral and Energy, 2006).

### 3.5 Sandstone

Sandstone of Mesozoic age occurs in several places in Ethiopia. In the Central part of the country deposits are found in Ambo, Jema, Muger and Abay. Similar deposits also found in the eastern and northern part of the country. Exploitation of such deposit is only occur in Ambo, at the place called Senkele (Figure 73).

The deposit is found in Shoa, near Ambo town at the locality called Senkele. The sandstone is accessible through Ambo-Guder Asphalt road, about 120 km west of Addis Ababa.

The Ambo sandstone belongs to the Adigrat Sandstone. It is Triassic to Jurassic in age. These sediments are found in the Guder valleys and side valleys and well exposed between Ambo and Senkele. The Adigrat Sandstone is generally white, yellow and red in color, predominantly micaceous, with intercalations of green shale (Mohr, 1971).

The Ambo sandstone exhibits a variety of different colour ranging from yellow, red to grey, which add a decorative value to buildings, walls and other constructions (Figure 74). The sandstone is fine grained, with coarse-grained layers, bedded with cross-lamination and composed of 95% quartz and about 5% kaolin (Walle and Heldal, 2001).
3.6 Volcanic Rocks

Volcanic rocks, ranging from the extensive plateau basalts, within the Early to Middle Tertiary Trap Series, to Quaternary lavas, tuffs and ignimbrite, cover a large part of Central Ethiopia. In many parts of the country, these volcanic rocks have, for many years, been a valuable source of cheap building material applied in local construction.

The Medhanialem Catholic Church near Legehaire and other old buildings in Addis Ababa are good example of ignimbrite used as dimension stone (Figure 76). Cobblestones made from different rocks including ignimbrite are currently used for construction of roads in Addis Ababa.

Volcanic rocks of Tertiary age, such as ignimbrite, tuff and basalt, can be good resources as construction material. Ignimbrite and tuff are mainly found near the rift valley. Basalts are found mainly in the highlands of central Ethiopia and in the rift valley.
3.6.1 Ignimbrite

Large deposits of tuffs and ignimbrites occur in the Rift Valley and surroundings of Ethiopia. These rocks are generally soft to carve and easy to split, and for a long time ignimbrite and tuff has represented the most important building stones of Addis Ababa Karstaedt and Mamo, 1986 (Figure 77).

![Figure 77 Exterior slabs showing stone architecture in Selase Cathedral Church (Addis Ababa).](image)

The rock is light brown to grey, fine to coarse grained, soft and contains scattered, white feldspar grains (1 to 3 mm) and rock fragments. The thickness of the workable ignimbrite bed is more than 6 m measured from the quarry floor.

In Addis Ababa especially around Bole and Kotebe there occur number of small quarries worked mainly by manpower and simple hand tools (Figure 78). The ignimbrites around these areas are soft, easy to work. Small, roughly shaped blocks are delivered from the quarries, while final shaping usually takes place at the construction site.

![Figure 78 Ignimbrite quarry near Bole](image)

These ignimbrite rocks are used for construction of houses, especially for foundations and exterior walls; fences, feeder roads and stairs.

There are enough resources of ignimbrite in the surrounding of Addis Ababa which is sufficient for a long period of time especially in the Bole and Kotebe areas (Karstaedt, 1985).

Ignimbrite deposits are also exploited several other places in the country. For instance, in Lalibela, where the famous rock-hewn churches of Lalibela were carved, quarries are still active to produce rocks for construction of local houses (Figure 79).
3.6.2 Basalt

Basalt of the Paleocene-Oligocene-Miocene age occupies the major part of the central Ethiopian plateau, and is widely used for local construction. Crudely shaped pieces are worked with simple tools and manpower, and used for walls of houses and fences (Figure 80).

In some areas, columnar basalt occurs. These have a natural, pentagonal joint pattern that can facilitate extraction and shaping (Figure 81). Other places, deposits of vesicular basalts are exploited.
4. Market

The markets for dimension stone have grown exponentially during the 1970s and 1980s, paralleling the improvement in stone-cutting technology. The ability to economically cut large blocks into thin slabs and tiles has made it much easier to use stone in commercial buildings and private homes. In 2003 an estimated 81 500 000 tons of stone were produced worldwide (Minerals and Metals Sector, Natural Resources Canada). The top five producing countries were China, India, Italy, Iran and Spain. Some countries are known for particular stone types (e.g., marble from Italy; granite from Canada, Brazil and India; and limestone from the United States) (Figure 82).

![World Dimension Stone Production, 2004](image)

*Figure 82 showing world production of dimension stone in 2004 (Source IMM Carrara)*

The dimension stone industry in Ethiopia is truly a local enterprise. Different types of dimension stone are quarried and marketed locally in rough, semi-processed or finished forms. Different markets demand different quality characteristics. At present dimension stone production is dominated by marble: About 8,100 tons of marble were produced in 2004, compared to 170 tons of granite, (Mitchell and Gebreselassie, 2007) (Table 2). Most of these stone products are featured on many commercial buildings in capital city Addis Ababa and in the regional towns like Diredawa, Bahir Dar, Awasa and Mekele (Figure 83).

“An excellent example of modern use of Ethiopian dimension-stone is the Sheraton Hotel in Addis Ababa, an ideal place to see most of the rocks presently under production (Daleti marble, Babile granite, Ambo sandstone, Addis Ababa ignimbrite, etc.) as facings, pavements, stairs and tabletops”. (Heldal and Walle, 2000) (Figure 84).

Currently, the Ethiopian dimension stone has good opportunities of external market. Exporting rough block is the most common way to get access to international market. Between 2001-2003 Ethiopia exports marble granite, basalt and travertine to the European market. (Table 2 ) (Mitchell, 2007) (Table2)

Ethiopia also imports dimension stone. According to Ethiopian Customs Authority about 30 tons of dimension stone were imported between 2000 and 2005 (Mitchell, 2007).

<table>
<thead>
<tr>
<th>Data</th>
<th>Saudi Arabia</th>
<th>South Africa</th>
<th>Egypt</th>
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<tr>
<td>Unit price (USD per ton)</td>
<td>202</td>
<td>356</td>
<td>628</td>
</tr>
<tr>
<td>Source ratio (Developed : Less-developed countries)</td>
<td>3:2</td>
<td>2:3</td>
<td>1:4</td>
</tr>
</tbody>
</table>

The major importers are: Saudi Arabia and South Africa with a significant import market in Egypt, Sudan and Kenya (Table 1).

*Table 1 Dominant regional importers of dimension stone (HS 6802)*
### Table 1 Exports of dimension stone, 2001-2003

<table>
<thead>
<tr>
<th>Marble, travertine… (HS 2515)</th>
<th>Year</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tons</td>
<td></td>
<td>592</td>
<td>600</td>
<td>132</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value in US$</td>
<td></td>
<td>240,2</td>
<td>261,8</td>
<td>67,138</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value in US$</td>
<td></td>
<td>72</td>
<td>33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US$ per ton</td>
<td></td>
<td>406</td>
<td>436</td>
<td>509</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Granite, porphyry, basalt… (HS 2516)</th>
<th>Tons</th>
<th>0.2</th>
<th>4</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tons</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value in US$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value in US$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US$ per ton</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Marble, travertine…, sawn or cut (HS 2517)</th>
<th>Tons</th>
<th>93</th>
<th>3</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tons</td>
<td></td>
<td>89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value in US$</td>
<td></td>
<td>1,544</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value in US$</td>
<td></td>
<td>1,544</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US$ per ton</td>
<td></td>
<td>515</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 83** White marble slabs decorating a residential building in Nazreth

**Figure 84** Modern use of dimension stone
- a) Daleti marble cladding modern building façade in Addis Ababa
- b) paving stone and bench of Babile granite (Sheraton Hotel)
- c) Wall decorated with Ambo sandstone (Sheraton Hotel (Photo by Haileyesus Walle))
5. Opportunity

The economic policy of Ethiopia allows and promotes the investment of private capital in the mineral sector. The Government has created a conducive environment to the participation of national and international companies in the development of the mineral industry. The metamorphic rocks of Ethiopia, offers a variety of rocks that already are either developed, or can be in the future, as important building stone resources (Walle and Heldal, 2001). The grey and white marbles of the western regions have already gained important industrial developments, and contribute today in shaping the image of building facades in Addis Ababa and other Ethiopian cities. There is still an interesting potential both for further development of industrial sized quarries in homogenous marble deposits and for finding more exclusive types for the export market. To this end the National Mining Corporation initiation to export marble to China, Turkey and Saudi Arabia markets is an attractive possibility.

Extraction of granite is still in its early beginnings in Ethiopia, but increasing knowledge of the resource potential combined with improved extraction methods could benefit a positive development. However, the granitoid deposits yet localized in Central, Southern Northern Ethiopia are of such types that generally meet high competition on the international market. The extensive deposits of post tectonic granite in Babile Dehan, Angerguten, Negash and other areas, offer an excellent opportunity for future development.

Both limestone and sandstone are extensively used in the domestic market. Both within the Adigrat sandstone and the Antalo and Hamanlei limestones there are still possibilities for exploration of new resources (Figure 86).
Table 3 Locations of known dimension stone deposits

<table>
<thead>
<tr>
<th>NAME</th>
<th>X-Coordinate(m)</th>
<th>Y-Coordinate (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Mankush Marble</td>
<td>114700.7619</td>
<td>1221156.595</td>
</tr>
<tr>
<td>2 Bulen &amp; Ganzi Marble</td>
<td>169250.3203</td>
<td>1174163.559</td>
</tr>
<tr>
<td>12 Daleti Marble</td>
<td>79836.83302</td>
<td>1095923.042</td>
</tr>
<tr>
<td>13 Anger Gut Granite</td>
<td>236299.0939</td>
<td>1013580.833</td>
</tr>
<tr>
<td>14 Ambo Sandstone</td>
<td>370862.9781</td>
<td>987587.3515</td>
</tr>
<tr>
<td>17 Wonchit &amp; Jema Limestone</td>
<td>470270.3692</td>
<td>1091543.44</td>
</tr>
<tr>
<td>15 Addis Ababa Ignimbrite</td>
<td>476422.95</td>
<td>991005.766</td>
</tr>
<tr>
<td>10 Melika Granite</td>
<td>479925.2107</td>
<td>658257.3377</td>
</tr>
<tr>
<td>11 Kenticha Serpentinite &amp; Soapstone</td>
<td>487248.8658</td>
<td>632939.6198</td>
</tr>
<tr>
<td>6 Degachebsi Limestone</td>
<td>836174.9792</td>
<td>1072088.441</td>
</tr>
<tr>
<td>16 Kombolch Granite</td>
<td>874513.8699</td>
<td>1042363.885</td>
</tr>
<tr>
<td>8 Hamaresa Granite</td>
<td>829368.742</td>
<td>1017695.737</td>
</tr>
<tr>
<td>9 Babile Granite</td>
<td>854895.895</td>
<td>1014294.642</td>
</tr>
<tr>
<td>3 Baruda (Moye, Gewi &amp; Ekonte) Marble</td>
<td>139510.5679</td>
<td>1170144.597</td>
</tr>
<tr>
<td>1 Mora &amp; Bapuri Marble</td>
<td>155721.3265</td>
<td>1169869.495</td>
</tr>
<tr>
<td>4 Dehan Granite</td>
<td>157467.0393</td>
<td>1151845.897</td>
</tr>
<tr>
<td>7 Hakime Gara Limestone</td>
<td>833496.4337</td>
<td>1025662.619</td>
</tr>
<tr>
<td>18 Zigi Soapstone</td>
<td>172666.8677</td>
<td>1182582.027</td>
</tr>
<tr>
<td>19 Dejen Limestone</td>
<td>409559.9301</td>
<td>1120088.644</td>
</tr>
<tr>
<td>20 Filiklik Limestone</td>
<td>417296.6547</td>
<td>1110839.755</td>
</tr>
<tr>
<td>21 Bure Granite</td>
<td>286555</td>
<td>1078206.564</td>
</tr>
<tr>
<td>22 Bure Sandstone</td>
<td>286969.5348</td>
<td>1080979.764</td>
</tr>
<tr>
<td>24 Enda Tikurir Marble</td>
<td>354535.7095</td>
<td>1551031.486</td>
</tr>
<tr>
<td>23 Kelafinos Marble</td>
<td>411568.7198</td>
<td>1516237.864</td>
</tr>
<tr>
<td>25 Newi Marble</td>
<td>446225.0826</td>
<td>1520126.81</td>
</tr>
<tr>
<td>26 Akmarra Marble</td>
<td>462641.5672</td>
<td>1499406.474</td>
</tr>
<tr>
<td>28 Naedir Marble</td>
<td>473135.0311</td>
<td>1487396.301</td>
</tr>
<tr>
<td>27 Filafi Marble</td>
<td>496091.8286</td>
<td>1549631.169</td>
</tr>
<tr>
<td>29 Berdada Marble</td>
<td>496440.2269</td>
<td>1542154.193</td>
</tr>
<tr>
<td>30 Negash Granite</td>
<td>560529.7184</td>
<td>1494612.195</td>
</tr>
<tr>
<td>31 Mosobo Limestone</td>
<td>568127.5424</td>
<td>1536035.056</td>
</tr>
<tr>
<td>32 Negash Slate</td>
<td>565693.7745</td>
<td>1530461.701</td>
</tr>
<tr>
<td>33 Hawzen Slate</td>
<td>535960.6457</td>
<td>1531795.026</td>
</tr>
<tr>
<td>34 Jilajile Slate</td>
<td>553351.4454</td>
<td>1578100.838</td>
</tr>
</tbody>
</table>
Figure 86 Locations of known dimension stone deposits
6. Reference


Potential of Tigral Region


About the Ministry of Mines

In compliance with the market oriented economic policy of Ethiopia, the parliament declared that it is the continuing policy of the Federal Government in the national interest to foster and encourage private enterprises in developing economically sound and stable mineral mining.

Accordingly, the Federal Government’s Ministry of Mines and Energy is responsible to administer and supervise all large scale mining operations including issuing prospecting, exploration and mining licenses for foreign investors and to these in joint venture with Ethiopians as per the reform issued in 1998 on the Mining proclamation following the realization of previous shortcomings of earlier laws and policies.

The reform clearly stipulated the responsibility of National Regional Governments to issue licenses and administer all small scale mining operations owned by Ethiopians and collecting all fees in addition to issue prospecting and exploration licenses for national investors.

Mining Legislation

In June 1993 new Mining and Mining Income Tax Proclamations were issued having considered knowledge-based experiences in some competitive countries and given the following provisions;

- Invite private investment in all kinds of mineral operations;
- Provides a prospecting license for one year;
- Provides an exploration license for an initial period of three years and renewed twice for one year each;
- Provides a mining license for 20 years and renewed for 10 years unlimitedly;
- Guarantee the licensee’s right to sell all the minerals locally or abroad giving marketing freedom;
- Provides for exemptions from custom duties and taxes on equipment, machinery, vehicles and spare parts;
- Gives securities of tenure;
- Gives clear provisions on fiscal and other issues;
- Considering taxation on repatriation of profits and capitals, a licensee shall pay a 2-5% royalty on ad Val Orem at production site, and a 35% income tax on taxable income. Taxable income is computed by subtracting from gross income for any accounting year all allowable revenue expenditure, a four years straight line depreciation, reinvestment deduction and permitted loses; and
The mining proclamation guarantees the opening and operation of a foreign currency account in banks in Ethiopia, retention of portion of foreign currency earning and remittances of profits, dividends, principal and interest on a foreign loan etc. out of Ethiopia.

Of course this fiscal package is still subject to frequent reviews for maintaining a balance between the objective of the government and investors as is evident by a series of amendments of the 1993.

INVESTMENT CLIMATE OF ETHIOPIA

The Federal Democratic Republic of Ethiopia has created a conducive investment environment to ensure and promote private investment to play a leading role in the development of the national economy.

This favorable climate for foreign investment has been created as consequence of the solid foundation of political and economic reform, particularly the stably secured macroeconomic reforms which are achieved by carefully managed sequential reforms coupled with faire fiscal and monetary policies. By the virtues of Ethiopia’s unique and untapped natural resources, its proximity to middle eastern and European markets, its 60 million population, and huge labor force both disciplined and easily trainable are some of the comparative advantages worthy of consideration while investing in Ethiopia. This is further enhanced by specific incentives and efficient administrative procedures.

Mineral Investment

Between 1974 and 1991 private investments were not allowed in the mineral sector. The government was fully responsible for the exploration and development of the sector, before the advent of the new economic policy of Ethiopia. In compliance with the new market economic policy of Ethiopia the parliament declares that it is continuing to update the policy of the Federal Government in the national interest to foster and encourage private enterprises in developing economically sound and stable mineral mining.

For a successful implementation of the policy, a number of steps have been taken aiming to boost the confidence of the private sector following the government’s strong believe that rapid mineral development can only be realized when the private sector is given full
right of operating managing and owning mineral enterprises. This is the underlined reason for the government’s active response to the concern of the International mining Companies. Accordingly it has restricted its role to basic mineral resources exploration, regulation and promotion only;

- to avoid the fear of controlling a large tract of prospective land by state owned companies, and
- to avoid the fear of seeable high risk due to unexpected unfair competition with state owned enterprises.

In this connection a measure stick for such track record of the government’s commitment is manifested by the privatized Lege Dembi Gold Mine, the only one government owned large scale gold mining, and the Kenticha Tantalum Mine which is already in the pipeline for privatization. This includes the reform of the mining law which is taking place since 1993 and many changes that have happened to justify the sincerity of the government.

Furthermore the commitment is much affirmed following the establishment of a fair and clear cut mining legislation giving investors assurances of the fruits of their success. It constitutes a fair setup of efficient and effective licensing and mineral right administration system, a fair set of environmental laws, rules to monitor and mitigate and reclamation effects by mining operation, fair laws to regulate the safety and health of the work fore and securing of tenure. It also gives freedom to license holders with a number of incentives including low royalty, exemption from custom duties and taxes on the equipment, machineries vehicles, and spare parts necessary for mineral operations with a 10 years provision to allow investors to carry forward losses.