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Natural stone in Ethiopia: report from the ETHIONOR program 1996-2001

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REPORT

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Summary:

The investigation and inventory of natural stone deposits in Ethiopia has been a subject within the Ethionor Mineral Resource Program, a cooperation between the geological surveys of Ethiopia (GSE) and Norway (NGU). In this report, a selection of Ethiopian natural stone deposits are presented, varying from Precambrian marbles and granites to Tertiary and Quaternary volcanic rocks. Some of the deposits are already subject to exploitation as natural stone, others are in the early stages of industrial developments or will possibly be in the future. Furthermore, some of the rocks described have potential for introduction to the international market, while others will also in the future be used only domestically.

Keywords:	Natural stone	Dimension-stone
Granite	Marble	Slate
Limestone	Sandstone	

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APPENDIX

1. INTRODUCTION

The main objective of dimension stone project, within the ETHIONOR Mineral Exploration Program, is to conduct an inventory work covering most dimension stone deposits and quarries throughout the country. On these facts, the project was run with the responsibility of GSE (Geological Survey of Ethiopia) geologists and one geologist from NGU (Geological Survey of Norway). Different types of deposits, quarries and processing plants were visited in order to obtain data on the types of deposits, location, accessibility, quality, reserves, etc. A total of 34 dimension stone deposits, including more than ten operating quarries, were visited. In addition, two dimension stone processing plants, NMC (National Mining Corporation) and EMI (Ethiopian Marble Industry), and the Saba Stone Products were visited.

Some historical sites, known for their stone architecture, were also included in the project, such as the Gondar castles, Lalibela rock hewn churches and Axum.

Special attention was paid to deposits in western Ethiopia, within the "core area" of the ETHIONOR project. In this part of the country, there are large deposits of marble, including the Mora, Bulen, Ekonte, Tulu Mony, Mankush and Daleti deposits. Some granite deposits in the same regions were also investigated, such as Dehan, Bure and Angerguten. In the east (Harrar), the Hakim Gara limestone deposit and the Babile and Hamaresa granite deposits were visited. Reconnaissance work in Central Ethiopia included volcanic rocks around Addis Ababa, limestone of Dejen and Jema and the Ambo sandstone. In the south, the Melika granite and the Kentich soapstone and serpentinite were visited. Some deposits of slate, granite and limestone in the Tigray region were investigated, whilst information about others (especially along the border with Eritrea) was collected from the Tigray Regional Mines office, due to the recent war between Ethiopia and Eritrea.

In the present report, a general description of deposits and quarry areas are given. For those parts of the country where more detailed mapping and exploration work have taken place during the program, separate reports have been given (Walle, etal, 2000). Chemical analyses, petrographic examinations and testing of physical properties have been carried out by the GSE laboratories.

2. NATURAL STONE: GENERAL CONDITIONS

"Natural stone" is a term applied to resources of solid rock that have certain valuable properties, which make them specifically useful as building material. Such properties may be technical quality or workability, or even beautiful colour and structure. Natural stones are used as they are created by nature. The only industrial process necessary to produce natural stone is shaping. "Dimension-stone" is a term frequently used on natural stone that are cut to size in standardized formats. "Building stone", or simply "stone", are more popular terms meaning the same as natural stone.

From an industrial point of view, natural stones are characterised according to their technical properties and aesthetic value rather than geological classification. For example, gabbros are often termed "black granite", since they are hard rocks, reminding of granites. Likewise, serpentinites are called "green marble" because they are as soft as marbles, and have a "marble-look". Many producers name their products (rocks) after the quarry place (Mora

marble) and/or their colour (Boka multicolour). Others find more "fancy" names for the stones for attracting customers. Limestone is frequently named "marble" if they can take a polish.

In most cases, architects and other consumers focus on the colour and structure of natural stone rather than the quality, and the price of stone on the export markets is almost exclusively dependent on the aesthetical appearance. However, petrographical examinations and testing of physical properties should be compulsory, in order to characterize the durability and range of applications for stones.

In the production of dimension-stone, the extraction of large, rectangular blocks is the fundamental part. Therefore, it is extremely important that the rocks are massive (few fractures) and uniform. Important aspects of geological investigations of natural stone resources are thus colour/structure, size of deposit/homogeneity, fracturing and quality. In addition, information about location, accessibility, source of energy, availability of water, market possibility, etc. is of great value. In many cases, geological exploration can be highly useful at an early stage in deposit evaluation, before costly pilot quarrying is initiated.

3. OUTLINE OF THE GEOLOGY OF ETHIOPIA

The bedrock geology of Ethiopia embraces a great variety of rock types within a wide age range (Mohr 1971, Kazmin 1972, Mengesh et al. 1996; Fig. 1). Precambrian metamorphic and igneous rocks cover 23% of the country, including some of the most interesting building stone sources, such as marble and granite. Thick successions of Palaeozoic and Mesozoic sediments (25%) overlie the Precambrian. These include building stone quality limestone and sandstone. Tertiary and Quaternary volcanic rocks cover a large part of the country (44%), and in these areas, basalts, tuffs and ignimbrites are extensively used for local housing and construction.

The Precambrian rocks of Ethiopia, upon which younger sedimentary and volcanic rocks were deposited, are exposed in the east central (Harar), west central (Gojam and Wellega), northern (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.

The Precambrian rocks can be divided into a Lower, Middle and Upper Complex (Kazmin, 1975). The Lower Complex comprises possibly Archean gneisses, migmatites and granites, forming a basement to the volcano-sedimentary successions of the Middle and Upper Proterozoic Complexes. These successions essentially show polyphasal deformation and low to medium grade metamorphism. However, the Proterozoic rocks of Northern Ethiopia, though strongly deformed, are only weakly metamorphosed.

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.

The Late Palaeozoic to Mesozoic sedimentary rocks of Ethiopia were deposited during a regional transgression of the Indian Ocean, followed by Late Mesozoic uplift and erosion (Kazmin 1972). In the western-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. The Adigrat sandstone varies in thickness from a few to 800 metres, and consists essentially of red to yellowish, well-sorted quartz sandstone. The upper part, however, is in places calcareous, particularly close to the transition to the overlying limestones of the *Antalo Group*. Thick limestones are developed in the middle part of this group, varying from near-shore, oolithic limestones, through fossiliferous, pale limestone and marl to black limestones deposited in deeper water. In the Harar area, a possible correlative to the Antalo Limestone, the *Hamanlei Series*, exhibits thick beds of pale, calcitic to dolomitic limestone.

A large part of Central Ethiopia is covered by volcanic rocks, ranging from the extensive plateau basalts, within the Early to Middle Tertiary Trap Series, to Quaternary lavas, tuffs and ignimbrite.

4. NATURAL STONE IN ETHIOPIA: EXPLORATION AND USES

Ethiopia has a long history in using stone for the construction of churches, palaces and, not at least, the Axum stelae (Fig. 2). The Lalibela churches are carved in soft ignimbrite, and the Gondar castles are built of local, easily available rock types. Traditionally, the use of stone in construction was considered to reflect high status. Stone ashlars and rubble were the materials of the landlords, while the peasants used wood. At present, the availability of wood is low in many places in Ethiopia, and the use of stone increase, also in rural areas, such as roofing slate in Tigray and basalt rubble in the central highlands.

Geological exploration of dimension-stone for industrial production has a short history in Ethiopia. GSE has a special responsibility regarding such, and has, in recent years, carried out exploration of several deposits of marble, limestone and granite in parts of the country. At present, the industrial development of such resources is increasing. Modern application of dimension-stone for building faces, stairs, pavements, etc. is commonly found in the large towns, e.g. Addis Ababa, Diredawa, Bahir Dar, Awasa and Mekele. 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.

Parallel to buildings and pavements, a large quantity of marble and limestone is used for memorial stone in Christian graveyards. For local housing, low-cost stone materials are preferred, such as ignimbrite, sandstone and basalt.

5. DEPOSITS WITHIN PRECAMBRIAN ROCKS

Concerning dimension-stone, some of the most important deposits are found within the Precambrian units. Of greatest importance during the latter 20 years, have been the large deposits of marble in the western part of the country. Marble has also been exploited in Tigray, and a number of deposits of granitoids and gneisses are being developed in several parts of the country. In addition, the Precambrian comprises deposits of slate, soapstone and serpentinite that can be of future interest.

Deposits of igneous rocks (granite, granodiorite, etc.) are found in all the Precambrian provinces, in the Harar area (Babile, Sukul, Kombolch, Fafem, etc.), in Tigray (Negash), in the south in Sidamo (Meleika and Negele), in the west of Welega (Angerguti) and Gojam (Metekel, Bure and Mankush).

Marble is essentially found in the western part of the country, in Gojam (Bulen, Mora, Ekonte, Bapuri, Baruda, etc) and Welega (Daleti, etc.). Deposits also occur in the Tigray region north of Adwa, Shiraro, Abergele, etc. The marble deposits cover large areas, but their quality (colour, texture, block size, degree of fracturing, etc.) varies considerably. Generally, the possibility of locating commercially interesting types of marble for domestic/export market is considered to be rich.

Other potentially interesting dimension-stone resources within the Precambrian include slate in Tigray around Adigrat and Hawzen, serpentinite in Sidamo around Kenticha and Kibremengist and talc in Chembi (Sidamo) and Zigi (Metekel). However, further detailed exploration work is needed.

6. MARBLE

6.1 Marble deposits in western Ethiopia

The most interesting deposits of marble are found in the western part of Welega (Daleti) and Gojam (Mora, Bulen, Mankush and Baruda; Fig. 3). The area is quite remote, and transport distance to Addis Ababa varies between 550 and 800 km, for the most part along non-paved roads. However, at present time, transport costs are still low enough for the marble producing companies to find the production profitable.

Most of the marble deposits found in these areas are hill forming, others have a flat, though well exposed, morphology. Predominantly, the marbles are calcitic, but white to grey dolomite occur as layers within the calcite marbles or as bordering units. The latter has, until now, not been of considerable interest as dimension-stone.

Several types of commercial marble occur in the area (Malis & Dejene 1983, Heldal et al. 1997). These include fine- to medium-grained, graphitic grey marble with white bands, medium- to coarse-grained white marble with grey bands, and several subordinate types such as pink, silicate-rich marble, pure white, fine-grained marble and sky blue to green marble. The latter two types seem to be connected to contact metamorphic aureoles around gabbroic intrusions. Grain-size varies from fine- to coarse-grained. Locally, the marbles have often a schistose, «slabby» appearance, and are not suited for production of squared blocks. Fold patterns may be very complex within some of the marble deposits, especially where competent layers of dolomite are intercalated with less competent calcite marble.

Pre-, syn- and post-tectonic dykes and veins of acidic and basic composition are common in several of the marble deposits, especially within coarse-grained, white to light grey varieties. Particularly, the foliation parallel, folded dykes cause problems for the extraction of marble, since they infiltrate a large part of the rock mass and are difficult to predict. Thus, in such areas, the block yield and the possibilities of using sophisticated quarrying technology, such as diamond wire sawing, are reduced. Furthermore, closely spaced joints cause similar problems in many cases. However, both the existing quarrying activity by several companies, and recent investigations by the GSE, indicate a fairly good potential for increasing the

production of low- to medium priced grey and white marble from the area, and a possible development of highly exclusive types of marble, such as pure white and sky blue varieties. The latter two may obtain very high price at the international market, but the deposits yet discovered are small and inhomogeneous.

6.2 Mora, Bulen, Ekonte, Bapuri-Sund, Tulu-Monye and Ganzi marble deposits

These marble deposits are found in the in the Metekel zone in the Benishangu-Gumuz region, concentrated within an area of 15 km radius. Generally, the marbles form hills, giving easy available deposits for commercial exploitation. The Mora, Bulen, Ekonte, Bapuri-Sund, Tulu-Monye and Ganzi marble deposits are fairly well known (Fig. 3, 4, 5 and 6), and some of them are at present time being exploited. EMI is mining the Ekonte marble while TAI (Tis Abay International Plc.) is planning extraction of the Tulu Monye and other marble deposits. Less known deposits (not to be included in the following descriptions), which may be of future interest, are found at Mohi, Addis Alem and Mentaweha.

Localization
Province- Gojam
District- Metekel (Bulen)
Localities- Mora (595km from Addis Ababa)
Bulen, Ekonte, Bapuri-Sund, Tulu-Monye and Ganzi

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

General Descriptions of Quarries and deposits
The Ethiopian Marble Industry (EMI) has for a long period exploited the Mora marble deposit, but transferred its operations to the Ekonte deposit some years ago. At present time, the Ekonte quarry is still active, and the production is primarily aimed for domestic consumption. In the Bapuri-Sund deposit, the Berta Company is exploiting white, coarse-grained marble.

In the Bulen and Ganzi marble deposits, no mining activity is at present time being carried out. With respect to the Bulen deposit, this can be due to a lack of commercial interest of the dark grey colour of the marble and to tight spacing of joints (Haileyesus et al. 2000). In the case of Ganzi, frequent veins and dykes combined with dolomitic layers in the white variety induce high waste ratio and thus reduce the commercial value of the deposit (Heldal et al. 1997).

The marble quarries 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 blocks is 1.15 ton, limited by the loading capacity of the transporting trucks.

In Tulu-Monye the apparent block size (rock volumes with no visible joints), ranges from 4x1.4x1.2m to 10x4.5x2.5 m., averaging 53m^3.

Macroscopic Descriptions

The deposits compose several varieties of marble, ranging from white, coarse-grained calcite marble with minor graphitic bands, to fine-grained, dark grey, banded graphitic marble with minor white bands (Fig. 7 and 8). In each deposit, both these types and intermediate varieties are present, but which is the dominating varies from one deposit to the next.

In the Mora, Ekonte and Bapuri-Sund deposits, white to light grey, coarse-grained marble dominates. Fine-grained graphitic marble is the most common type in the Bulen deposit. The Tulu-Monye marble is almost similar to the Bulen deposit, but contain less amounts of graphite. The Ganzi deposit exhibits approximately equal amounts of white and graphitic marble. The Tulu-Monye deposit seems, compared to the others, less fractured and of better value regarding the extraction of commercial sized blocks.

Chemical Analyses

	SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O	LOI	P_2O_5
Mora	0.8	0.01	0.08	0.1	51.4	1.1	0.1	0.1	42.5	0.04
Bulen	1.9	0.6	0.14	0.1	53.9	0.93	0.1	0.1	41.56	0.1
Bapuri	0.2	0.1	0.01	0.1	54.9	0.88	0.1	0.1	42.67	0.11
Ekonte	0.76	0.16	0.37	0.1	53.2	1.63	0.1	0.1	42.63	0.07
Tulu-Monye	0.84	0.15	0.29	0.02	53.67	0.82	0.01	0.01	42.79	0.02
Ganzi	0.1	0.2	0.02	0.1	54.6	0.59	0.1	0.1	42.67	0.11

Table 1

Physical Properties

	Mora	Bulen	Bapuri	Ekonte	Ganzi	Tulu-Monye
Dry Density (g/cm^3)	2.72	2.85	2.7	2.8	2.75	-----
Bulk Density (g/cm^3)	2.73	2.70	2.7	2.7	2.7	2.75
Porosity (%)	0.40	1.1	0.62	0.8	1.39	0.77
Water Absorption (%)	0.12	0.41	0.68	0.31	0.52	0.29
Compressive Strength kg/cm^2	430-1125*	-----	-----	580	----	768

Table 2

* range of values is related to differing orientation of layering in the tested samples.

Mineralogy

Mora	**Bulen**	**Bapuri**	**Ekonte***	**Ganzi**	**Tulu-Monye**
Calcite 98%	Calcite 70%	Calcite 85%	Calcite 85%	Calcite99%	Calcite 91%
Opaque <1%	Graphite 25%	Dolomite 5%	Opaque 12%	Opaque1%	Opaque 9%
Quartz <1%	Calcite 5%	Opaque 10%?	Dolomite 3%		
Pyrite <1%		Quartz =Trace			
		Apatite = Trace			

Table 3

* Only one sample is examined, and may not be representative.

Comment: all the marbles can be classified as calcite marbles. The Bulen marble has generally a higher content of graphite than the others.

Prevalent applications
All the described types of marble are suitable for both exterior and interior applications, as slabs or massive works.

Reserves
Estimated total reserves are 64.554×10^6 tons in the Mora deposit, 6,270,800 tons in the Tulu-Monye deposit, and 24.51×10^6 in the Bulen deposit. For the other deposits, no data are available.

6.3 Daleti Marble

The Daleti marble deposit is one of the largest in Ethiopia, and exhibits a variety of marble types. It has been exploited for a long period of time (Fig. 9a), and is extensively used for facades and floors all over Ethiopia.

Localization
Province- Wolega
District- Mendi
Locality- Daleti (635km from Addis Ababa)

Geological setting
The marble is found within Proterozoic metasedimentary and metavolcanic successions (quartzite, greenschist, schist and marble). Mafic and granitic intrusions, formed at various stages in the tectonothermal history of the supracrustal rocks, are common in the area. The surrounding highland is capped by Tertiary basalt and tuff.

General description of the quarry
The National Mining Company (NMC) operates several quarries on the Daleti marble. The most important types are the coarse-grained with green patches ("Multicolour" type), the grey marble and the fine- to medium-grained white marble. The extraction of pink and sky blue marble is, at present time, only supplementary.

The extraction techniques are highly sophisticated, where both cutting by diamond wire and water-jet technology are applied. For the multicolour and grey types, due to the wide spacing of joints, a high portion of large blocks is possible.

Macroscopic descriptions
Several types of marble occur in the area, including; coarse-grained white marble with minor graphitic bands (Fig. 9b); coarse-grained graphitic marble with white bands; coarse-grained, white marble with fine-grained, green to grey patches; fine- to medium-grained, white marble. In addition, small deposits of pink, silicate rich marble and sky blue marble (Fig. 9c) occur, the latter restricted to contact zones around basic dykes.

The marbles are calcitic, but with small amounts of dolomite, graphite, quartz and (for the pink type) phyllosilicates. Quartz is usually present as nearly horizontal veins and as scattered aggregates.

Prevalent applications
All the described types of marble are suitable for both exterior and interior applications, as slabs or massive works. Cut and polished slabs show a smooth and bright surface without chips and pits.

Reserves
A total of 2,8 mill. m^3 of marble reserves is reported from the area.

6.4 Mankush marble

The marble deposits in the Mankush area constitute low, rounded hills in the otherwise flat area (Fig. 10a). Graphitic grey marble, pure white marble and pink marble are found. Thus, the area comprises several types of commercial interesting types. However, parallel and crosscutting dykes and veins of amphibolite and granite are common (Fig. 10b), leaving relatively small volumes of exploitable marble.

Localization
Province- Gojam
District- Metekel
Locality- Guba or Mankush (705km from Addis Ababa)

Geological setting
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.

General description of the quarry
The EMI and the BERTA companies carry out pilot quarrying in the area. The operations are similar to that of the Ekonte and Bapuri areas, i.e. small-scale quarries with the use of hand held drilling and wedging as the primary extraction method.

Macroscopic description
Three types of marble can be recognised in the area. These are coarse-grained, white marble with minor graphitic bands (Fig. 11a), grey graphitic marble with white bands and coarse-grained pink marble with silicate layers (Fig. 11b). The latter type is much less common than the former two.

Chemical Analyses

SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O	LOI	P_2O_5
0.9	0.01	0.05	0.1	54.5	0.8	0.1	0.1	42.2	0.04

Table 4

Physical Properties

Dry Density (g/cm^3)	2.9
Bulk Density (g/cm^3)	2.7
Porosity (%)	1.1
Water Absorption (%)	0.4

Compressive Strength --

Mineralogy
Calcite = 85%
Opaque = 10%
Quartz = 5%
Apatite = Trace

Prevalent application
The marbles are suitable for all types of external and internal application, such as building facades, floors, stairs and paving.

6.5 Marble deposits in Northern Ethiopia

The marble deposits of Northern Ethiopia (Fig. 12) occur within the Arabian-Nubian shield, and have a tectonic setting similar to the western and south-western Ethiopia, within successions of metavolcanic and metasedimentary rocks of upper Proterozoic age, which are intruded by basic to acidic intrusions. However, since the metamorphic grade in the marbles is lower than farther to the south, the marbles of Northern Ethiopia appear more fine-grained. The basement rocks constitute about 68% of the total surface area of the region. The geology of the region is diversified and complex, and favourable for both metallic and non-metallic mineral deposits.

6.6 Enda Tikurir Marble

The deposit is found in western Tigray, in the Adi Aseri village, 52 km southwest of Shiraro and 153 southwest of Shire-Endassilase. The distance to the port of Massawa (Eritrea) is 486km. The area can easily be reached by the Sheraro-Humera road

The deposit area is found between 14° 2'-14° 12'N Lat and 37° 35' 22"-37° 45'E Long.

Localization
Province- Western Tigray
District- Shiraro
Locality- Adi Aseri

Geological Setting
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. Outcrops are found in the Tekeze gorge and on a ridge extending towards Wolkaite area. The marble is enveloped by chlorite schist intercalated with slate (eastern side) and mica schist (western side). Along the contacts, the marble is foliated and not of any commercial value.

Macroscopic description
The marble is medium-grained, compact and has a light yellow, smoky white and "multi-colour" appearance. Regular sets of joints and wide spacing of them contributes to the production of commercially sized blocks of 1 x 0.8 x 1.5m. 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.

Quality
No chemical analyses, petrographic descriptions and tests of physical properties are present.

Prevalent Application
According to the data obtained from the Tigray Region Mines office, the marble can be used for internal and external building purposes such as facing, stairs, pavements and tabletops.

Reserves
The estimated reserves are between 190 and 220 mill. m^3 (Tigray Region Mines office).

6.7 Newi Marble

The deposit occurs in Central Tigray, 42 km north west of Abi Adi (30 km from Adwa and 395 km from the port of Massawa). The deposit can be reached through Abi Adi-Newi dry weather road.

The deposit area is found between 13° 46'-13 ° 54'N Lat. and 38 ° 30' – 38 ° 45'E Long., in the Kola Tenben - Woreda area.

Localization
Province- Central Tigray
District- Kola Tenben
Locality- Newi

Macroscopic description
The marble is fine- to medium-grained, compact with black and dark grey colour.

Prevalent application
The marble can be used for internal and external building purposes.

Reserves
The estimated reserve is between 12 and 13 mill. m^3. The average block size is 2.5 x 2 x 1.5m.

6.8 Akmara marble

The deposit is located in Central Tigray in the Meteka Woreda area, south of Abi Adi, and nearly 397 km from the port of Massawa. The area is accessible via the Abi Adi - Newi dry weather road. The deposit area is found between 13° 34' – 13 ° 46' N Lat and 38 ° 38' – 38 ° 46' E Long.

Localization
Province- Central Tigray
District- Meteka
Locality- Akmara

Geological setting
The marble forms a ridge striking NE-SW from Dedere, via Bambo-Shewi, to Tekeze.

Macroscopic description
The marble is fine- to medium-grained, white and smoky white in colour.

Prevalent application
For external and internal building faces, stairs and pavements

Reserves
The estimated reserves are 12 mill. m^3.

6.9 Dichenamo marble

The deposit occurs in western Tigray, 30 km from Shiraro.

Localization
Province- Western Tigray
District- Shire (Shiraro)
Locality- Dichinamo

Macroscopic description
The marble is fine- to medium-grained, and appears in several colour varieties, such as grey, purple, multi-colour, rose and green (Fig. 13).

General description of the quarry
No geological report or laboratory analysis has been carried out. According to the information from the Saba stone-processing factory, it is extensively used as dimension stone in the domestic market. In the quarry, diamond wire sawing is used for primary extraction of blocks. Processing is done at the Saba plant in Adwa.

Quarry location	Product name	Price(Birr) per $1m^2/1cm$	Price (Birr)per $1m^2/2cm$	Price (Birr)per $1m^2/3cm$
Shiraro-Dichinamo	Grey	302.95	330.36	369.11
Shiraro-Dichinamo	Purple	302.95	330.36	369.11
Shiraro-Dichinamo	Multi-colour	302.95	330.36	369.11
Shiraro-Dichinamo	Rose	302.95	330.36	369.11
Tekeze-Temben*	Black	317.93	346.44	387.38
Tekeze*	Black	168.46	216.62	246.76
Hagereselam-Togoga*	Grey	168.46	216.62	246.76

Table 5
Dichinamo marble, final products and prices of slabs (Data from Mekele sales office, June 2000)
*Limestone.

The Saba processing plant also produces "Terrazzo tiles" (25x25 cm). The price range is between 71.49 and 107.22 Birr, depending on the quality of the cement.

Prevalent application
The marble can be used for different types of interior and exterior applications, such as building faces, stairs, pavements and tabletops. An example of use in Addis Ababa is the facade of the Mega building at Bole road, clad with purple marble from Dichinamo. The slabs show sharp cut edges, smooth surfaces with no pits or grooves.

Reserves
No reserves estimates are reported.

7. GRANITE DEPOSITS

"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.

In Ethiopia, known deposits of "granite" predominantly fit the definition of "true" granites, or granodiorite. The commercial quality of granite deposits depends on several factors in addition to its appearance on polished surfaces, e.g. colour and texture. Homogeneity it is considered to be an important factor when trading dimension-stone, and the deposits should not contain high amounts of veins and dykes, and inclusions such as xenoliths.

Intrusive igneous rocks are common in the Precambrian of Ethiopia, ranging from granitic bodies within the migmatites of the Lower Complex, to pre-, syn and post-tectonic intrusives in the Middle and Upper Complexes (Kazmin 1972, Heldal et al. 1997). The Lower Complex is possibly of Achaean age, and at present time deposits are being exploited in the Harar area.

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.

7.1 Granite in Harar area (eastern Ethiopia)

Granite exposures in Harar are found on the road from Diredawa to Harar in the Hamaresa area (Hasenge and Sukul) and around Babile and Fafem on the road leading to Jijiga 30-34km from Harar.

The Hamaresa granite is found 8km from Harar (6 km asphalted and 2 km dry weather road). Also, granite deposits are found in the Kombolcha area, 17 km north of Harar.

Localization
Hamaresa granite;
Province- Harar
District- Harar
Locality- Hamaresa

Babile granite;
Province- East Harar
District- Babile
Locality- Babile

Macroscopic description
According to the report of Harar Planning Office, the Hamaresa granite has a colour of white grey to pink. Boulders, which are seen in the outcrop area, have an average height of 15 m. The granite body strikes N-S, and has three major joint directions with wide angles to each other. At some places, the granite is weathered to an average depth of two metres. Pilot mining was carried out by ELMICO (Ethiolibian Mining Company). 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.

The Babile granite is situated close to Babile town on the Harar-Jijiga road. The deposit constitutes massive boulders and smaller hills (Fig. 14a), which give good opportunity for the extraction of commercial size blocks. At present time, this deposit is exploited by NMC. The Babile granite is medium grained, pink to red with dark patches (Fig. 14b, 15); and has a variegated, veined structure, reflecting its close relation to the surrounding migmatitic gneisses. Within small areas, the structure of the granite may vary from strongly banded to massive (Heldal, et al. 1997). The potential for locating new granite deposits in Harar is large and one should also consider the possibility of finding hill forming migmatites, which may be of interest.

Reserves
Hamaresa granite1,5 mill. m^3 (Hasenge); 0,4 mill. m^3 (Sukul; data from Harar planning office report of 1990). No data is available for the Babile granite.

7.2 Bure and Angerguten Granites

Deposits of medium- to coarse-grained, pink to grey and porphyritic granite are found within the western part of the country, extending from Angerguten in Welega to Bure in Gojam (Fig. 16). Several deposits of this type are found in the area, forming smooth hills with a steep foliation. The NMC is at present mining the granite in one of the Angerguten hills using drilling, blasting and wedging methods (Fig. 17).

Localization
Bure;
Province- Gojam
District- Bure (Bekotabo)
Locality- Bekotabo

Angerguten;
Province- Welega
District- Angerguten
Locality- Angerguten

Geological setting
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 sub-vertical. The granites commonly form hills with prominent cliffs.

General description the deposit
Granite boulders are common in the outcrop areas, on hills and along stream valleys. The possibility of extracting commercially sized 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.

Macroscopic description
The Bure 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. The granite is overall pink in colour and weakly foliated, locally with a more strongly developed, "gneissose" foliation. On the surface, granite boulders are common (Fig. 17a).

The Angerguten granite is in composition, colour and texture similar to the Bure granite (Fig. 18). Boulders are also common in this locality.

Chemical analyses

SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O	H_2O	LOI	TiO_2	P_2O_5
68.12	14.85	3.51	0.05	1.42	1.01	3.75	5.02	0.47	0.44	0.68	0.38

Table 6

Physical properties

Bulk density (g/cm^3)	2.67
Porosity (%)	1.262
Water absorption (%)	0.474
Compressive strength (kg/cm^2)	753

Mineralogy
(Bure granite)

K-feldspar	55%
Quartz	25%
Plagioclase	9%
Biotite	5%
Muscovite	5%
Others	1%

Prevalent application
This rock can be recommended for internal and external facing, pavements and tabletops. It is frequently used in the Sheraton Hotel, Addis Ababa.

Reserves
No detail exploration work has been done on these granite deposits. However, huge outcrop areas indicate that there may be sufficient resources for a large industrial activity.

7.3 Dehan granite

The Dehan granite is pink with greenish spots, and forms large hills and ridges in the area between Mora and Galesa. The granite is coarse-grained, slightly foliated and seems homogeneous in colour and texture. Easily extractable, large boulders are common in the area (Fig. 19). Rarely, biotite-rich inclusions occur. In the peripheral part, the Dehan granite is slightly more fine-grained than in the central parts. Locally, the granite is altered (greenish) and more fractured. The most interesting aspects of the Dehan granite are the assumed high potential for extraction of large, homogenous blocks (without dykes and inclusions) and the low content of dark minerals, such as biotite.

Localization
Province- Benishangul-Gumuz
District- Metekel
Locality- Mora

General description of the deposit
Compared to many other granite deposits in Ethiopia, the Dehan granite seems to have a uniform, pink colour with low content of mafic minerals (Fig. 20). The sizes of the boulders (up to $50m^3$) indicate potential for large blocks. TAI is at present doing exploration work on the deposit.

Chemical Analyses

SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O	LOI	P_2O_5
70.94	14.15	2.14	0.07	1.87	0.41	4.28	4.58	0.92	0.01

Table 7

Physical properties

Dry Density (g/cm^3)	2.7
Bulk Density (g/cm^3)	2.7
Porosity (%)	1.2
Water Absorption (%)	0.4
Compressive Strength (kg/cm^2)	1253

Mineralogy

Quartz	30%
Plagioclase	20%
K Feldspar	27%
Biotite	4%
Sericite	6%
Epidote	6%
Chlorite	3%

Prevalent application
The Dehan granite is expected to be suitable for all kinds exterior and interior uses as dimension-stone.

Reserves
Reserves (covering two hills along the road) are estimated to 7 mill. tons.

7.4 Negash granite

There are a number of granite deposits in the northern part of the country, especially in the Tigray region. The Negash granite is one of several deposits, and has been mined by ELMICO in the past. Leftover extracted blocks are found at the quarry site. The deposit is located in eastern Tigray, 55km from Mekele town in Negash Woreda on the Mekele - Adigrat road. The granite body is found between the coordinates 39° 36' 3"- 39 ° 36' 37" E and 13 ° 53' 30"- 13° 54' 49"N

Localization
Province- West Tigray
District- Negash
Locality- Negash

Geological setting
The area is dominated by Late Proterozoic metasedimentary and metavolcanic rocks, which 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.

General condition of the quarry and deposit
National Mining Company started quarrying in the southeastern part of the deposit, and some remaining granite blocks (less than 10 in number) are still found in the quarry (Fig. 21a). It seems that the long distance to the company's processing plant in Awash is an important reason for the stop in production. The colour of the Negash granite seems more preferable than the Babile and Angerguten granites, due to its low mica and higher K-feldspar content. The Saba stone processing plant in Adwa is nearer to the quarry, but so far this plant is only equipped for the processing of marble and limestone.

Macroscopic description
The granite is medium-grained, and pink to light brown in colour (Fig. 21b). Major minerals are quartz, K-feldspar (microcline), plagioclase, and muscovite. The granite is well exposed, and forms a N-S oriented ridge.

Chemical analyses

SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O	H_2O	LOI	TiO_2	P_2O_5
70.08	15.78	1.18	0.02	1.14	0.31	4.70	3.64	0.50	0.74	0.17	0.21

Physical analyses

Bulk density (g/cm^3)	2.623
Porosity(%)	1.14
Water absorption (%)	0.44

Mineralogy

Quartz	35%
Microcline	33%
Plagioclase	27%
Muscovite	5%
Opaque	Trace
Zircon	Trace

Prevalent application
The granite can be used for interior and exterior decoration of building faces, stairs and pavements.

Reserves
According to the Tigray mines office report estimated reserves are 58 mill. m^3.

7.5 Other granite deposits

Several granites are mapped as post tectonic (Late Precambrian to early Palaeozoic) in the Adola–Sidamo area. Some of them are, however, deeply weathered. Pilot quarrying of fine-grained, pinkish grey granite has been carried out near Kibremengist in a locality called Meleika (Fig. 22). The granite is fine- to medium-grained and equigranular. The biotite content varies significantly, and in biotite-rich zones a weak foliation is developed. Minor amount of veins and inclusions are seen. Spacing of joints and fractures vary from tight along the slopes of the hill to moderate approaching the central part. Due to varying colour and the joint pattern and frequency it seems not likely that the deposit could give a high output of export quality blocks. On the other hand, the expected good cleavage properties of the granite may facilitate extraction of blocks and production curbs and paving stone.

In the Tigray region, there are several other granite occurrences that probably represent interesting dimension-stone prospects. These are the Embamadre granite, the Kisadima granite, the Gemhalo microgranite and the Badime granite, all in Western Tigray. Furthermore, more than twenty granite occurrences, still to be evaluated, could be of interest.

8. SERPENTINITE AND SOAPSTONE

These rocks are found in the Upper Complexes of both the Sidamo and the Gojam areas. Deposits in Sidamo-Kenticha and in Metekel-Zigi areas (Gojam) were visited during the project period (Heldal et al. 1997). They belong to the Upper Proterozoic Complex of the Adola and Birbir group respectively.

Serpentinites (generally green with white veins) are often referred to as "green marble" on the international market. Such rocks have been used in Europe as decorative stone since the anitquity, and well known types include several Italian deposits, such as the "Verde Antique". Serpentinites do predominantly belong to low and medium price levels. Soapstones are geologically tightly linked to serpentinites, but are not that well established at the international market. However, such rocks are increasingly used for fireplaces and even building stone in Northern Europe, and there might be a future market development stimulating the exploitation of such deposits in many places around the world.

In Kenticha, South Ethiopia, isolated, lens shaped serpentinite bodies occur within amphibolite units. The serpentinites are folded and foliated, and are enveloped by talc schists. Talc rich zones are also found in shear zones within the serpentinites. The green serpentinites apparently seem highly fractured at the surface, but from superficial investigations it is difficult to separate penetrative joints from selective weathering of carbonate veins. Thus, more detailed investigations by core drilling and sampling are necessary before any conclusions are reached concerning sub-surface quality of the serpentinite.

The talc zones (Fig. 23) observed in Kenticha essentially contain talc, chlorite and rusty spots that probably represent weathered, Fe-rich carbonate, such as magnesite; the depth of this stained weathering profile is yet not known, since only superficial sampling has been carried out. Further knowledge on this is of vital importance both for investigations of potential soapstone and industrial talc deposits. The talc-rich rocks are essentially medium- to coarse-grained, flaky and have a greenish to grey colour. Both massive and schistose zones are observed, the former concentrated in fold hinge zones along the margins of the serpentinites. These fold hinges are of special interest, since the deposits are thickened in these areas, and the soapstones have a more massive appearance than in the thinned limbs.

The soapstones in Metekel-Zigi area in Gojam occur in the transition zone between the ultramafic parts of layered intrusions (Grenne et al. 1998) and the surrounding metasediments. As in Kenticha, interchanging massive (Fig. 24) and schistose soapstone is found. Rusty weathering seems, however, to be less intense than in Kenticha, and it should be possible to obtain fresh rock almost at the surface. In conclusion, both areas have an interesting potential for soapstone deposits, though further investigations, especially concerning the depth of the weathering of magnesite in Kenticha, are necessary.

9. SLATE IN TIGRAY

Slate occurrences are reported only from the northern part of the country, in the Tigray region. According to the Tigray mines office, there are several slate occurrences in the area, of which the most interesting are Jilajile, Mebelet, Negash and Howzen. Slate is extensively used by the local people for roofing and wall constructions. Only the Jijajile deposit was visited during the ETHIONOR project period.

9.1 Jilajile slate

Localization
Province- East Tigray
District- Adigrat
Locality- Jilajile (5km east of Adigrat)

Geological setting
The slate deposit forms a continuous ridge from Mayawlie towards Jilajile. It is overlain by the Adigrat sandstone (west) while dolomite occurs beneath the slate on the eastern side. The deposit covers an extensive area of about 700 m by 2 km. The slab thickness (e.g. the spacing of the cleavage) varies from less than a centimetre up to 10 cm, and the surface of the cleft slabs is quite irregular (Fig. 25). Thus, until better deposits are located, the quality of the slates from Tigray seems not very promising for industrial scaled operations. Relatively wide

spacing of joints allows slab sizes of ca. 1.5 m by 2.1 m. The unit strikes $N10^0E$, dipping 45^0NW.

Macroscopic description
The slate is fine grained and the colour on split surface is predominantly greenish-blue, but locally bluish black occurs.

Chemical and physical analyses are done from one of the slate deposits near the Negash town.

Chemical analyses

SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O	H_2O	LOI	TiO_2	P_2O_5
63.98	17.07	6.46	0.02	0.09	1.37	0.01	4.34	0.73	0.73	0.93	0.30

Table 9

Physical properties
Bulk density (g/cm^3) 2.727
Porosity (%) 3.28
Water absorption(%) 1.21

Prevalent application
Traditionally, people in the Tigray region have been using slate for roofing and pavements. The use of slate in other parts of the country is limited.

10. MESOZOIC ROCKS

Three major lithological divisions are recognized in the Mesozoic rocks of Ethiopia, which are deposited during transgression followed by regression of the Indian Ocean over the Horn of Africa. These are the Adigrat Sandstone, the Antalo Limestone and the Upper Sandstone. The Adigrat Sandstone is a transgressive unit ranging from Upper Triassic age in the southeast part of the country (Ogaden) to Lower or Middle Jurassic in the northwest. The Adigrat Sandstone is resting unconformably on the Precambrian rocks, overlain by the Antalo Limestone and the Upper Sandstone.

The Antalo limestone and its equivalent in the Hakimgara area in Harar is a good source for dimension stone, and in the latter area there has been production for many years. Other deposits of well-bedded limestone where there are a potential for extraction of blocks are situated in Gojam and Shoa in Abay, Muger and Jema river gorges. Extraction of the Adigrat Sandstone takes place in the Ambo area, and there are also possibilities of locating interesting sandstone deposits other places.

11. LIMESTONE

Calcitic limestone of dimension-stone quality is predominantly found within the Jurassic Antalo limestone (central part of the country – such as the Harar area) and the Hamanlei Series (east central part). 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 such as the Jema, Wonchit and Muger valleys.

11.1 Hakimgara

In the Hakimgara area, a large deposit of creamy coloured to yellowish limestone is found (Fig. 26b and 27). The horizontal beds vary in thickness, where the thicker beds are considered to be of best quality as dimension stone (Fig. 26a). Dark grey, large and small spots, frequently oriented parallel to beds, occur within the deposit. These probably relates to differences in the concentration of organic matter and/or reduction fields along bed contacts.

Localization
Province- Harar
District- Harar
Locality- Hakimgara

General description of the quarry
The extraction of blocks is done by drilling and wedging. However, diamond wire sawing and use of dynamite cord has been practised by the NMC. The latter may generate micro-fractures in the limestone, thus reducing the quality as dimension stone.

Macroscopic description
The Hakimgara limestone is calcitic in composition and has a low content of silica. It appears homogeneous, with the exception of the dark spots. Two major sets of vertical joints are seen in the deposit. These are widely spaced and occur perpendicular to each other, thus facilitating the extraction of squared blocks. Limestone blocks as dimension stone have been exploited for a long time in this area, and at present quarries are operated by the NMC and EMI companies.

Chemical analyses

SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O	LOI	P_2O_5
2.8	0.6	0.28	0.1	53.2	0.6	0.1	0.2	42.7	0.04

Table 10

Prevalent application
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.

11.2 Delga Chebsi limestone

The Delga Chebsi limestone deposit occurs within the Early to Late Jurassic Hamanlei series. The limestone horizons, alternating with sandstone and (subordinate) marl, may reach thickness of 10 to 50 metres. The bedding dips gently 20° - 35° towards south. The deposit is influenced by two fault systems striking E-W to WNW-ESE and NE-SW respectively, and fracturing is therefore a problem in parts of the deposit. Three sets of joints are common. The limestone is fine-grained, fossiliferous and the colour varies from yellow (dominant) to green/grey or pink. The colour variation can be due to the content of organic maters. High

content of organic matter gives grey colour, whilst pink and yellow colouration relate to content of limonite.

Localization
Province- Diredawa area
District- Shinile
Locality-Delga Chebsi

Quality
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 narrow spacing of joints, which is seen in large parts of the deposit, is, however, of greater importance to the possibilities of dimension stone production, as it can be difficult to locate placed were the average block size is sufficient large. A detailed geological survey would be necessary in order to clarify these matters.

Chemical analyses

SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O	LOI	P_2O_5
2.2	0.2	1.98	0.1	52.8	1.0	0.1	0.1	41.6	0.06

Table 11

Reserves
The reserves are roughly estimated to minimum one million cubic metres (Schlede, et al. 1990).

Prevalent application
Unless less fractured parts are discovered, the deposit is probably only suited for the production of limestone chips.

11.3 Jema and Wonchit

The Jema and Wonchit limestone deposits have a light-yellow, creamy colour. The limestone forms steep cliffs within the river canyons, some which could be accessible for exploitation. The near horizontal beds vary significantly in thickness, where the thickest (and most favourable regarding extraction) occur in the lower part of the deposit (Fig. 28). In the upper part, the limestone beds seem more extensively fractured, and may only be suitable for limestone chip production. Three 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. The block yield will probably be better in other, less fractured parts.

Localization
Province- Northern Shoa
District- Merhabete
Locality- Jema

Geological setting
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.

Macroscopic description
Limestone layers are normally compacted, microcrystalline, fossiliferous, light grey and grey to creamy in colour. 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.

Chemical analyses

	SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O	LOI	P_2O_5
Jema	1.5	1.0	0.37	0.1	51.56	0.6	0.09	0.04	43.5	0.01
Wonchit	2.04	0.35	0.27	0.1	52.85	0.34	0.01	0.01	43.3	0.01

Table 12

Prevalent Application
The thick, lower beds are less fractured and can probably be exploited as dimension stone. The limestone is dense and compact, and appear to be usable for most dimension-stone applications.

11.4 Mosobo limestone

Localization
Province- East Tigray
District- Mekele area
Locality- Mosobo

This deposit is found approximately 20km from Mekele town, along the Mekele-Adigrat road.

Geological setting
This limestone unit is located near the Agula River, covering an area of 150,000m^2. Two major fault systems are present in the area, striking N20^0 E and N 70^0 W.

General condition of the quarry and deposit
Pilot quarrying was carried out by the Saba Stones Company. The excavated limestone blocks still remain on the quarry site (Fig. 29). However, extraction was stopped due to the poor quality of the deeply weathered limestone. Brown spots, grooves and pits on the surface and the overall weakness of the slabs are among the features that make any regular use of the limestone in the shape of slabs difficult.

Macroscopic description
White to greyish-yellow, fine-grained crystalline limestone containing spare fossil fragments. The horizontally bedded limestone is extensively fractured, with three sets of joints oriented perpendicular to each other. The limestone is weathered at least for several metres below surface. There are also indications that weathering affects the rock even deeper, along fractures and bedding planes.

Chemical analyses

SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O	H_2O	LOI	TiO_2	P_2O_5
13.47	1.05	1.01	0.04	25.02	18.31	0.17	0.06	0.26	40.19	0.04	0.21

Table 13

Prevalent application

The deposit is probably only suitable for local housing, possibly also for limestone chips.

Reserves
According to the field observation, measurements, and data from the Tigray mines office, the blocks have an average size of 1.5x2x1.7 m and the estimated reserves are 9 mill. m^3.

There are other limestone deposits in the Tigray region, which can be of better quality as dimension stone, but no geological investigation has so far been carried out. These deposits include the South Abi Adi limestone, the Abergele limestone and the Gogan Daero limestone.

11.5 Dejen and Filikilik Limestone Deposits

These limestone deposits are situated on the two opposite sides of the Abay canyon, near the Addis Ababa – Debre Markos road. The limestone is here approximately 400 metres thick, and occurs between the Upper Shale and the Trap Series basalt. 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 (Fig. 30). The colour of the limestone varies from light yellow to grey and brownish grey. 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 montmorilonite) occur on the bed surfaces. Steep cliffs and rock fall along them are common in the area.

Localization
Province- Gojam and Shoa
District- Dejen and Goha Tsion
Localities- Gelgel and Filikilik (Gelgel is 215 km while Filikilik is 195 km from Addis Ababa)

Geological setting
The sedimentary rocks of the Abay gorge are predominantly Mesozoic, starting with Triassic sandstone in the bottom. The Jurassic limestones reflect a coastal lagoon sedimentary environment, including coral reef limestone. The stratigraphy of the Abay gorge is similar to the Jema and Wonchit area described above.

General condition of the deposits
Parts of the deposits seem to exhibit relative thick beds of massive limestone (especially the upper part), and there is a potential for exploiting dimension stone. The deposits on both sides of the gorge must be considered as large. Both are easy to reach from the road between Addis Ababa and Debre Markos. Probably, the Dejen limestone is more accessible and easier to exploit than the Filiklik deposit, due to a more gentle morphology.

Physical properties

Density (g/cm^3)	2.366
Porosity (%)	11.390
Water absorption (%)	4.815

Prevalent application
The limestone can be used for any type of construction works for external and internal building faces, pavements and stairs.

12. SANDSTONE

Sandstone of Mesozoic age occurs several places in Ethiopia. In the Central part of the country, deposits are found in Ambo, Jema, Muger and Abay. Deposits are in addition found in the eastern and northern part of the country. At present time, exploitation of sandstone as building stone only occurs in Ambo.

12.1 Ambo sandstone

The deposit is found near the town of Ambo. The sandstone exhibits a variety of colours, yellow, red and grey, which add a decorative value to buildings, walls and other constructions where the rock is used. The sandstone is thick-bedded and massive, and easy to quarry by simple hand tools (sledge hammer, wedges, chisels, etc.). Finished products (slabs, ashlars, etc.) are worked on the quarry site. The Ambo sandstone is extensively used in Ethiopia, especially in and near Addis Ababa (Fig. 31).

Localization
Province- Shoa
District- Jibat and Mecha
Locality- Ambo-Senkele (120km from Addis Ababa)

Geological setting
The Ambo sandstone belongs to the Adigrat Sandstone unit of Triassic to Jurassic age. In the area, the Mesozoic sediments are exposed in the Guder catchments, and there are several outcrop areas of the sandstone between Ambo and Senkele. According to Mohr (1971), the Adigrat Sandstone is characterized by white, yellow and red sandstones, predominantly micaceous, with intercalations of green shale.

General description of the quarry and quality
The sandstone is easy to wedge and work with simple tools. Blocks are extracted from the sandstone beds by primary wedging, and then further divided by smaller wedges to smaller formats. Chiselling does final shaping. The sandstone is quite porous and poorly cemented.

Macroscopic descriptions
The Ambo is essentially fine-grained, but with coarse-grained layers. Horizontal beds with tabular cross-lamination are the most common sedimentary structures. Volcanic rocks overlie it, and impure sandstone is found along the contact.

Mineralogy
Quartz=95%
Kaolin=5%
Others=0.4%

Prevalent application
The sandstone is predominantly used for the facing of houses and fences. It is not recommended to use it in stairs, floors and pavements, due to its weak strength and low resistance to mechanical wearing.

12.2 Bure Sandstone

Localization
Province- Gojam
District- Bure
Locality- Bure (42 km from Bure town on the Bure-Nekemt road)

Geological setting
The sandstone at Bure belongs to the Adigrat Sandstone. In the Bure area, it can be seen resting unconformable on top of basement rocks, and the unconformity is exposed in road cuts. In the area, the Adigrat Sandstone measure approximately 200 metres in thickness, and is overlain by the Trap Series volcanic rocks.

General description of the deposit
The deposit is located near an all-weather road, and thus, easy accessible for exploitation. The horizontal sandstone beds are of different thickness, but essentially they seem to be sufficient thick for exploitation, and in general, the possibility of large blocks seems better than the Ambo deposit. The ridge forms a steep cliff on the western side and a gentle slope on the southern. The quality of the sandstone has not been properly investigated. It appears "soft" and porous on the surface, but testing of fresh samples should be carried out before any conclusions are to be made.

Macroscopic description
The sandstone is pink to yellow in colour and has a fine- to medium-grained texture. On weathered surfaces, a deeper, red colour is common. At the locality, the sandstone occurs in thick beds (up to 8 m) showing internal cross-stratification (Fig. 32). Three sets of joints are observed with spacing approximately 0.5-1.5 m. The deposit forms an E-W oriented ridge, where it should be possible to locate areas suitable for extraction.

Physical properties (weathered sample)

Bulk density (gcm^3)	2.059
Porosity (%)	21.885
Water absorption (%)	10.531

Prevalent application
As the Ambo sandstone, the Bure sandstone should be used mainly for facing of houses etc.

13. TERTIARY 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. There are a large number of quarries in the central highlands of Ethiopia, and only some representative examples will be treated here.

Volcanic rocks of Tertiary age, such as ignimbrite, tuff and basalt, can be good resources as construction material is found in different parts of the country. Ignimbrite and tuff is mainly found near the rift valley and basalt in the central plateau.

13.1 Ignimbrite

In and near the Rift Valley, large deposits of tuffs and ignimbrites occur. 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 & Wondafrash 1986). For example most of the feeder roads in Addis Ababa are constructed of such rocks. Other examples are the stairs leading to the Natheret school of Addis Ababa and the Catholic Church near Legehare (Fig. 33b). A number of small quarries are worked in the vicinity of the city, mainly by manpower and simple tools (Fig. 33a). Due to their softness, such rocks are, however, not very suitable for use as paving stone and stairs. Ignimbrite deposits are also exploited several other places in the country. For instance, the famous, rock-hewn churches of Lalibela are carved in such, and these rocks are also used in modern times for local construction in the area.

13.2 Ignimbrite Around Addis Ababa

The ignimbrites around the capital are soft rocks, easy to work and, of course, easy accessible. Small, roughly shaped blocks are delivered from the quarries, while final shaping usually take place at the construction site.

Localization
Province: Addis Ababa
District : Bole-Kotebe
Locality: Bole-Kotebe
The road to the Bole International Airport can be used to access the quarry area. (There are other ignimbrite deposits around Addis Ababa but the only data available is for the Bole-Kotobe ignimbrite).

Macroscopic Descriptions
The ignimbrite is found as well-bedded deposits resting on basalts, dipping gently towards the southeast. The colour is light brown to grey. The rock is porous, soft and contains scattered, white feldspar grains (1 to 3 mm). The thickness of the workable ignimbrite bed is more than 6 m measured from the quarry floor. Locally, the ignimbrite is deeply weathered, and thus of poorer quality for construction purposes.

Geological Setting
The geology of Addis Ababa is dominated by the central Ethiopian Trap-Series volcanics, which is a result of widespread volcanic activity of Tertiary to Quaternary age. The Trap-Series is divided into two groups: the older Ashenge Group (basalts, rarely tuffs and agglomerates) and the younger Magdala Group (basalt with interbedded trachyte and volcano-sedimentary intercalations). It is the Magdala group that dominates in the Addis Ababa area.

General Description of Quarries and Deposits
A large number of quarries are situated in the area, including the ones described here. Daily production reaches several hundreds of cubic metres, applied in various constructions in the capital.

Prevalent Application
This ignimbrite rock is used for construction of houses, especially for foundations and outer walls. In addition, it is applied for fences, feeder roads and stairs. The rock is soft and should not be applied in high-traffic areas.

Reserves
Although the reserves are not calculated, they are considered to be large and sufficient for a long period of time, unless urbanization occupy the quarry areas.

13.3 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. In some areas, columnar basalt occurs (Fig. 34a). These have a natural, pentagonal joint pattern that can facilitate extraction and shaping. Other places, deposits of vesicular basalts are exploited (Fig. 34b).

14. CONCLUSIONS

Ethiopia exhibits a variety of rocks that already are either developed, or can be in the future, as important building stone resources. 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.

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 also in this part of the sector. However, the granitoid deposits yet localized in Central, Southern Northern Ethiopia are of such types that generally meet high competition on the international market.

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, though limited to the relatively small areas where these units are exposed.

The, perhaps in volume, most important part of the Ethiopian building stone production, is the exploitation of volcanic rocks for local housing and, close to the capital, for more industrial scaled construction work. Such resources represent a considerable potential for low-cost supply of an excellent construction material, and could be further developed.

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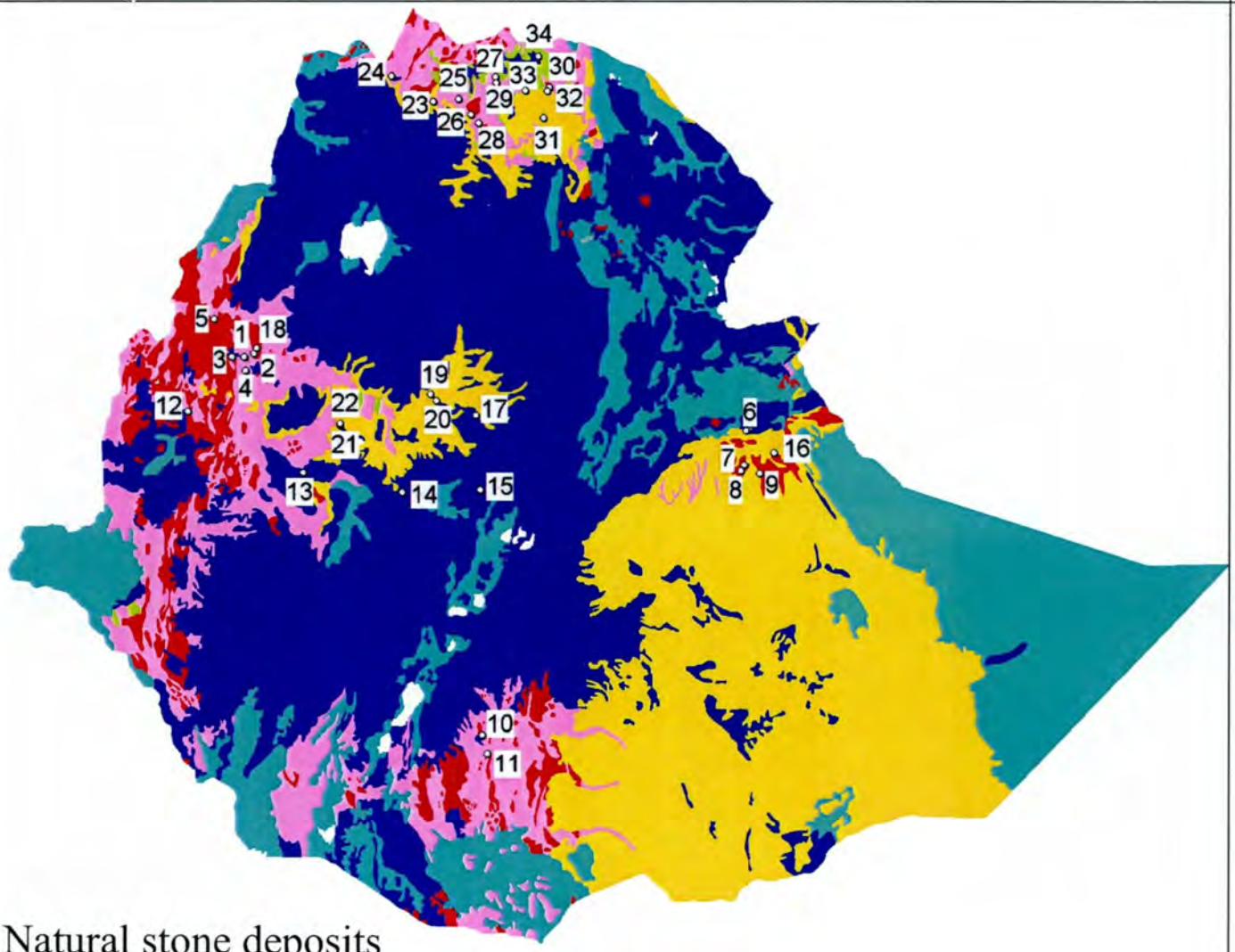


Natural stone deposits

1 Mora & Bapuri Marble
2 Bulen & Ganzi Marble
3 Baruda (Moye, Gewi & Ekonte) Marble
4 Dehan Granite
5 Mankush Marble
6 Degachebsi Limestone
7 Hakime Gara Limestone
8 Hamaresa Granite
9 Babile Granite
10 Melika Granite
11 Kenticha Serpentinite & Soapstone
12 Daleti Marble
13 Anger Guti Granite
14 Ambo Sandstone
15 Addis Ababa Ignimbrite
16 Kombolch Granite
17 Wonchit & Jema Limestone
18 Zigi Soapstone
19 Dejen Limestone
20 Filiklik Limestone
21 Bure Granite
22 Bure Sandstone
23 Kelafinos Marble
24 Enda Tikurir Marble
25 Newi Marble
26 Akmara Marble
27 Filafil Marble
28 Naedir Marble
29 Berdada Marble
30 Negash Granite
31 Mosobo Limestone
32 Negash Slate
33 Hawzen Slate
34 Jilajile Slate

Legend

- Tertiary and Quaternary sedimentary rocks
- Tertiary and Quaternary volcanic rocks
- Mesozoic sedimentary rocks (sandstone and limestone)
- Palaeozoic rocks
- Precambrian igneous rocks (predominantly granite)
- Precambrian metamorphic rocks (gneiss, schist, marble and metavolcanic rocks)

Figure 1
Simplified geological map of Ethiopia and distribution of natural stone deposits.

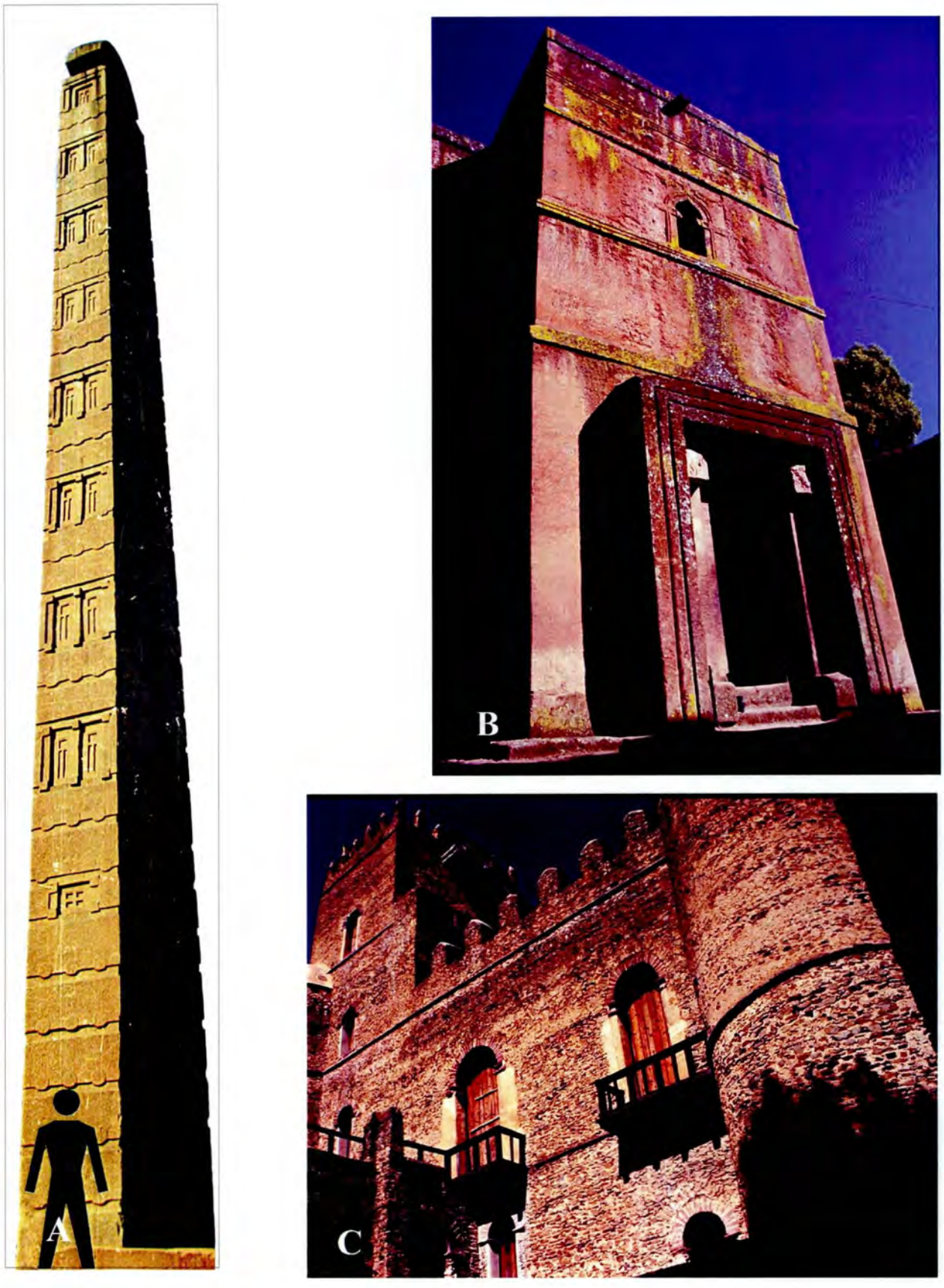
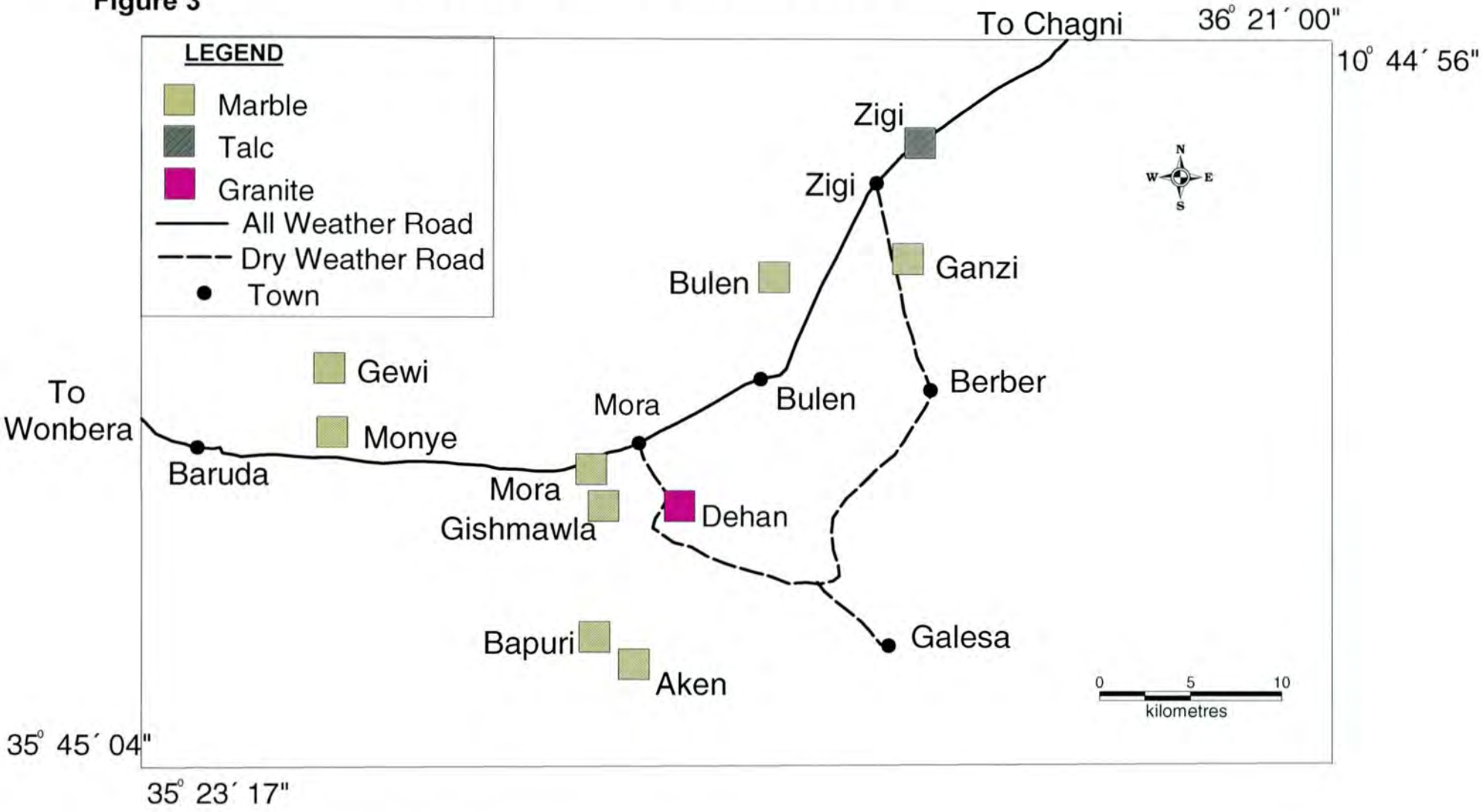


Figure 2
Historical sites Built of natural stone in Ethiopia.
A) a phonolite obelisque in Axum - related to a man's size.
B) The St. George church of Lalibela - carved in red ignimbrite.
C) The fasileda palace in Gondar. Basalt rubble and ashlars of ignimbrite.

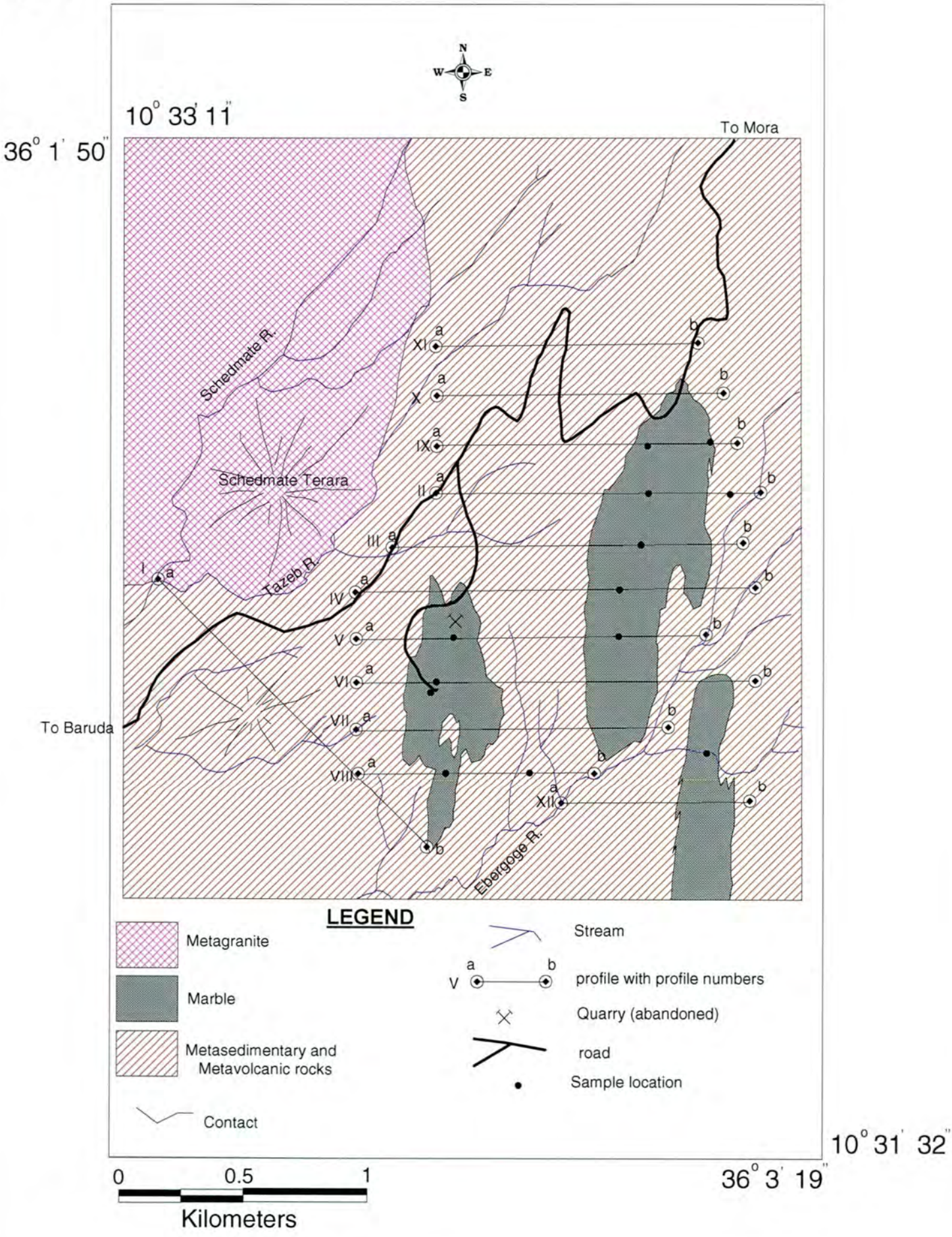
Location map of some dimension stone deposits in Benishangul-Gumuz region

Figure 3



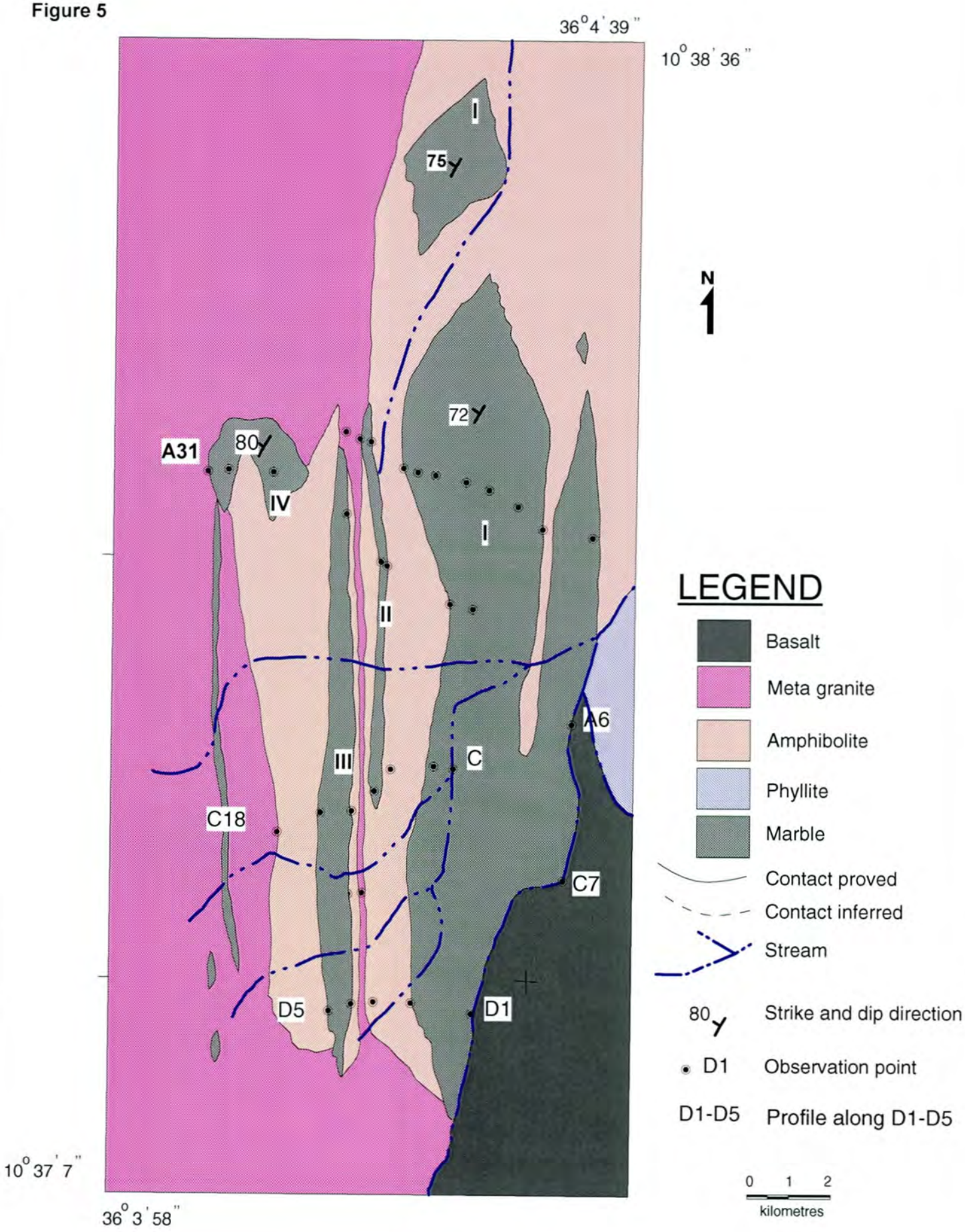
GEOLOGICAL MAP OF MORA MARBLE

Figure 4



Geological Map of Bulen Marble

Figure 5



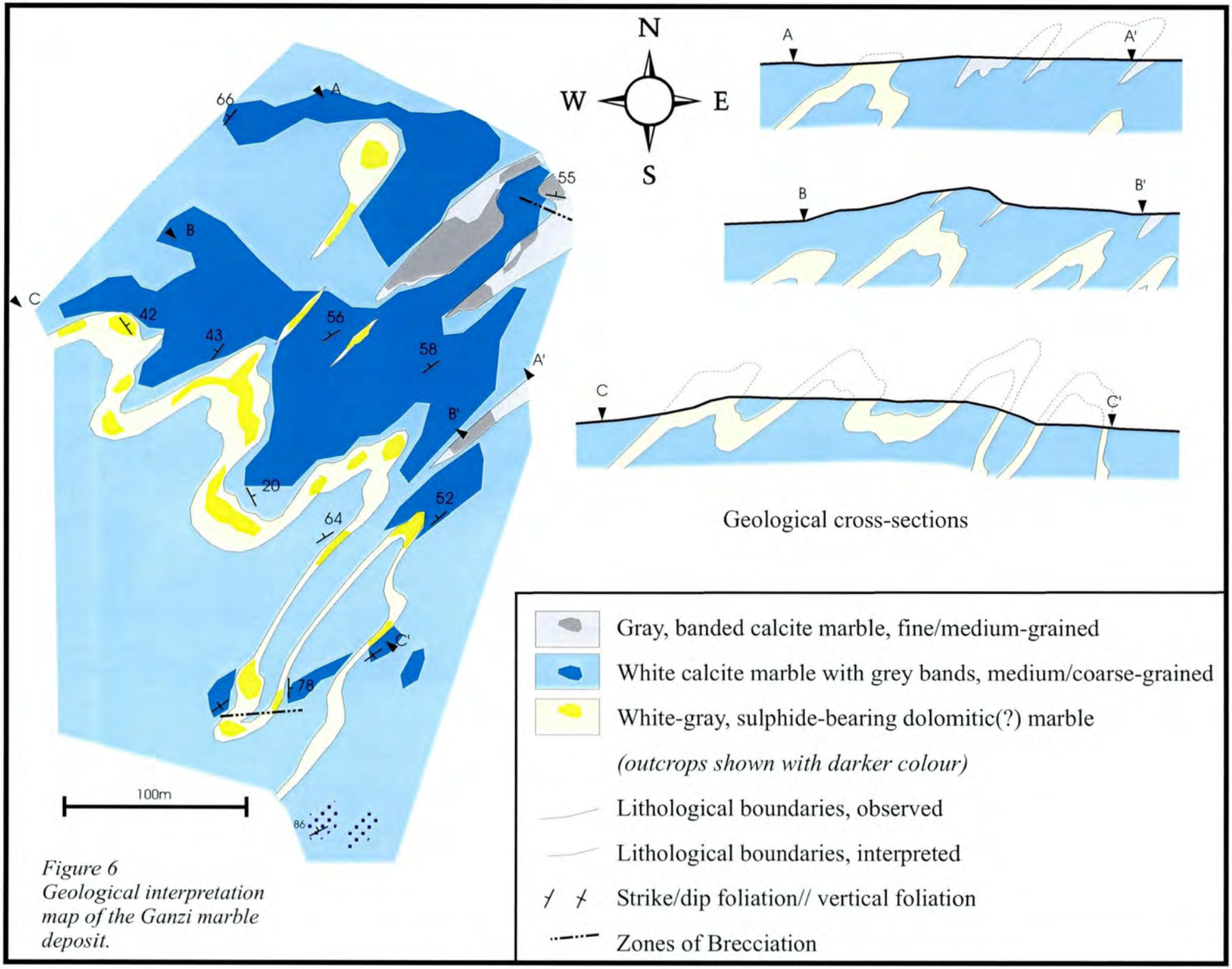


Figure 6
Geological interpretation map of the Ganzi marble deposit.

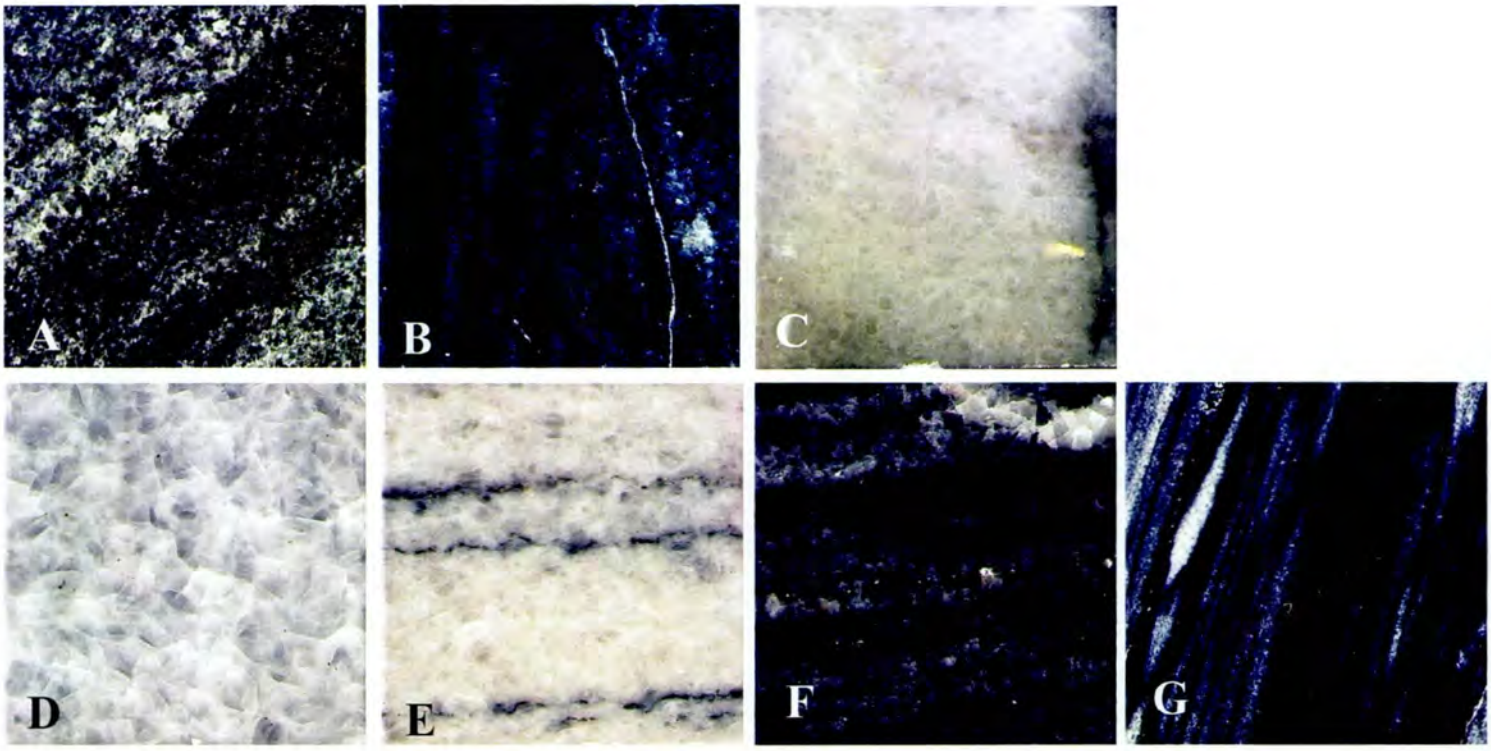


Figure 7 (above)
Polished samples of marble from Gojam.
A) Bulen. B) and C) Ganzi. D) Ekonte. E) Mora. F) and G) Tulu-Monye.
Scale 1:1.
The colour may deviate from the original samples.

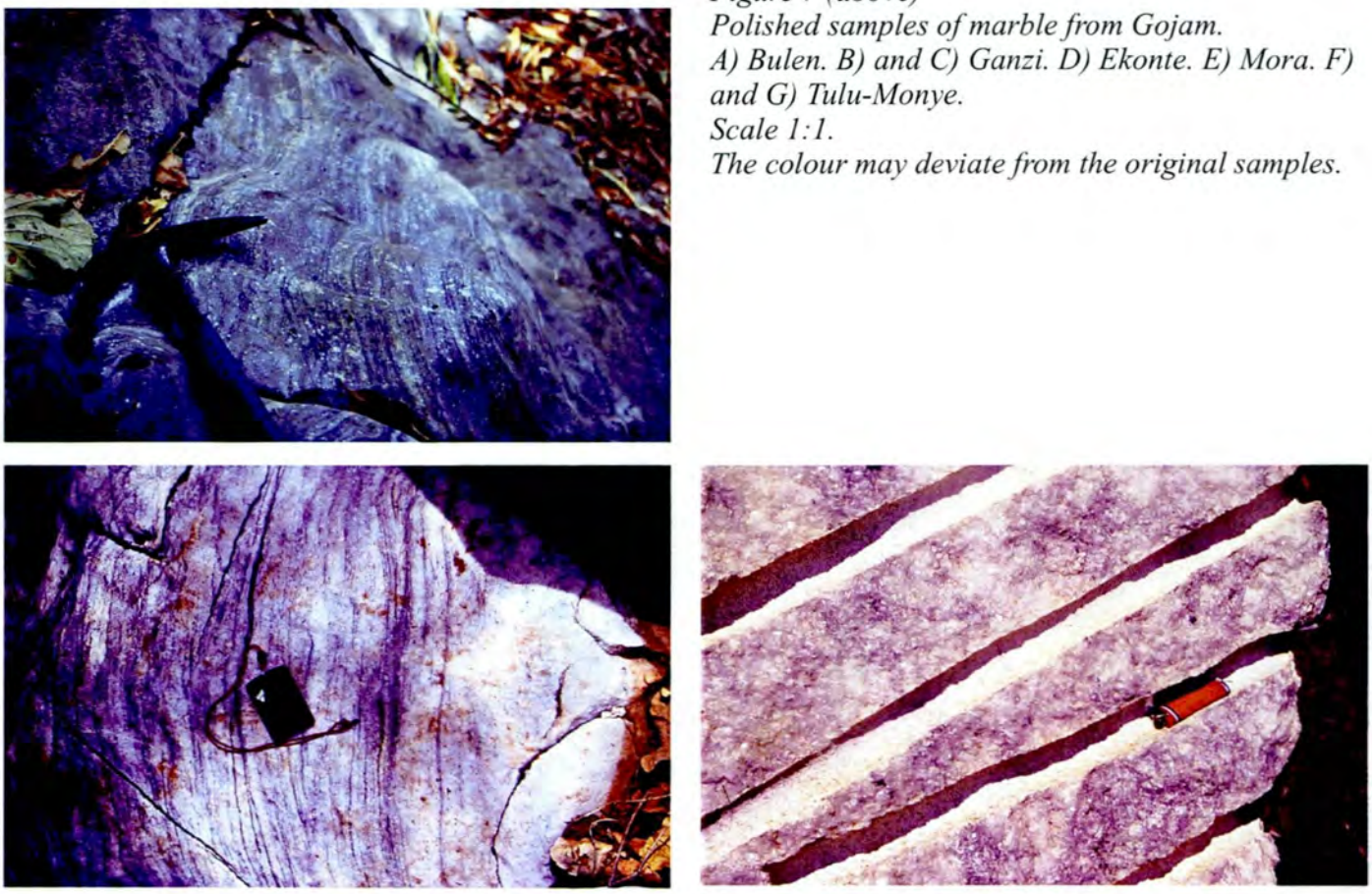


Figure 8
A selection of Gojam marbles as they appear in the field. A) Grey marble, Ganzi. B) White marble with grey veins, Ganzi. C) White marble, Mora (block from trial quarrying).

Figure 9
A) From the Daleti marble quarry (multicolour type).
B) Daleti marble cladding modern building facade in Addis Ababa.

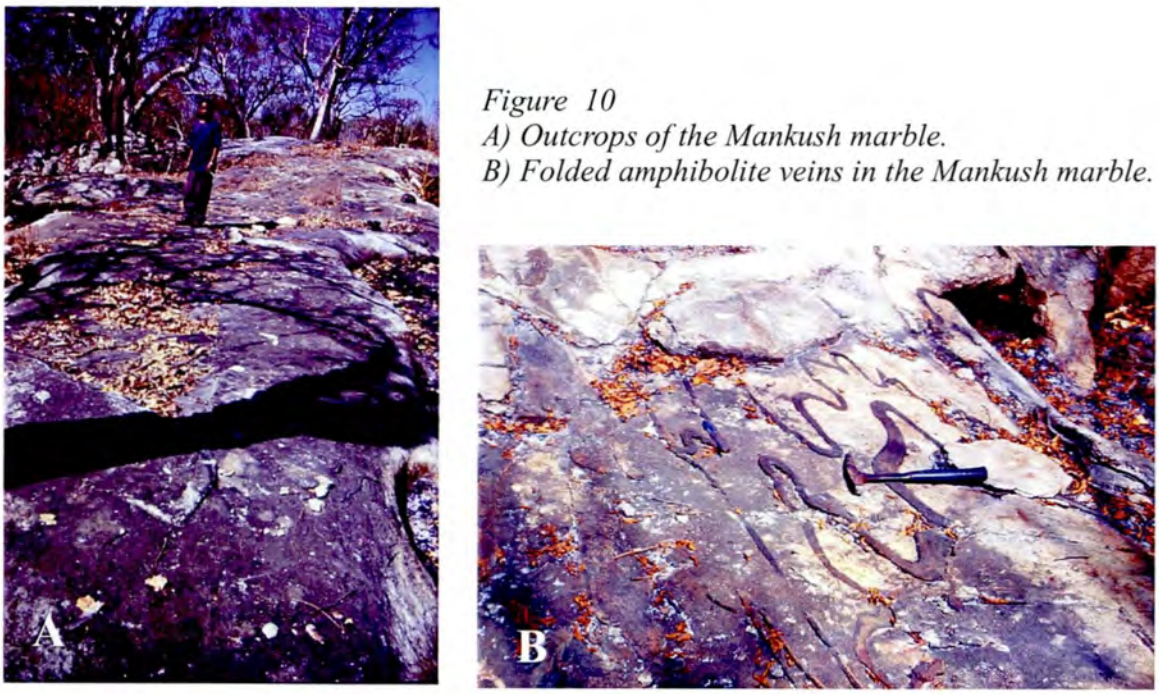


Figure 10
A) Outcrops of the Mankush marble.
B) Folded amphibolite veins in the Mankush marble.

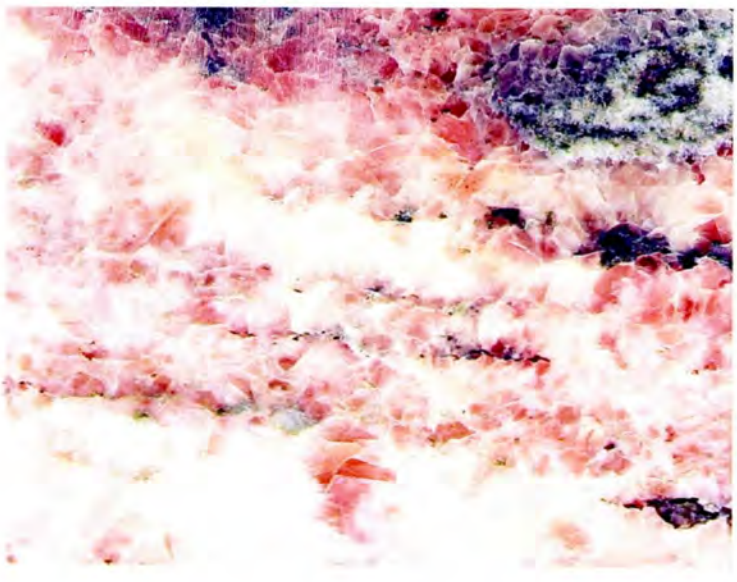
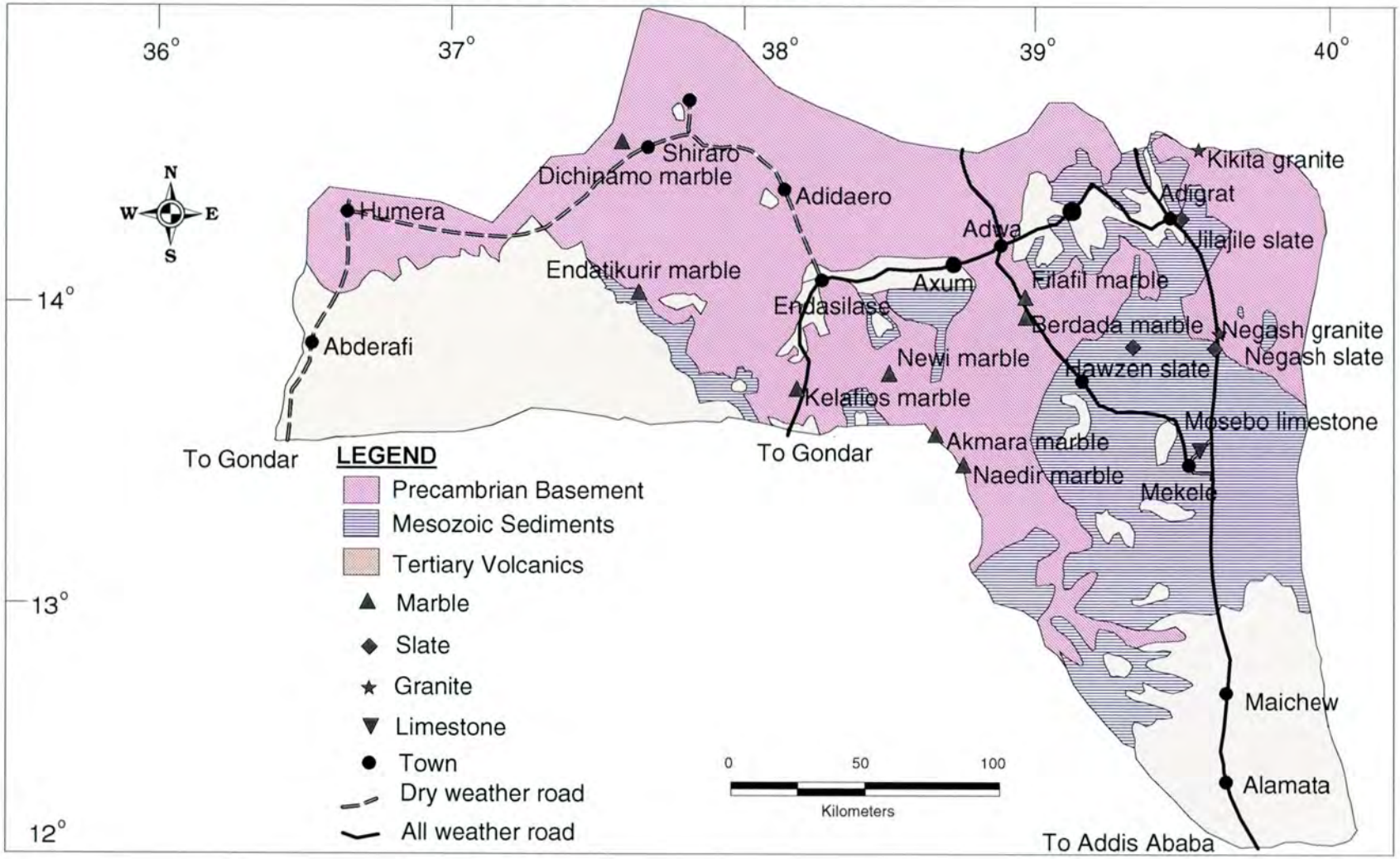


Figure 11
Polished slab of pink marble from the Mankush deposit. Scale 1:1.

SIMPLIFIED GEOLOGICAL MAP OF TIGRAY REGION WITH SOME DIMENSION STONE DEPOSITS

Figure 12

(Geological map from Tigray mines office)



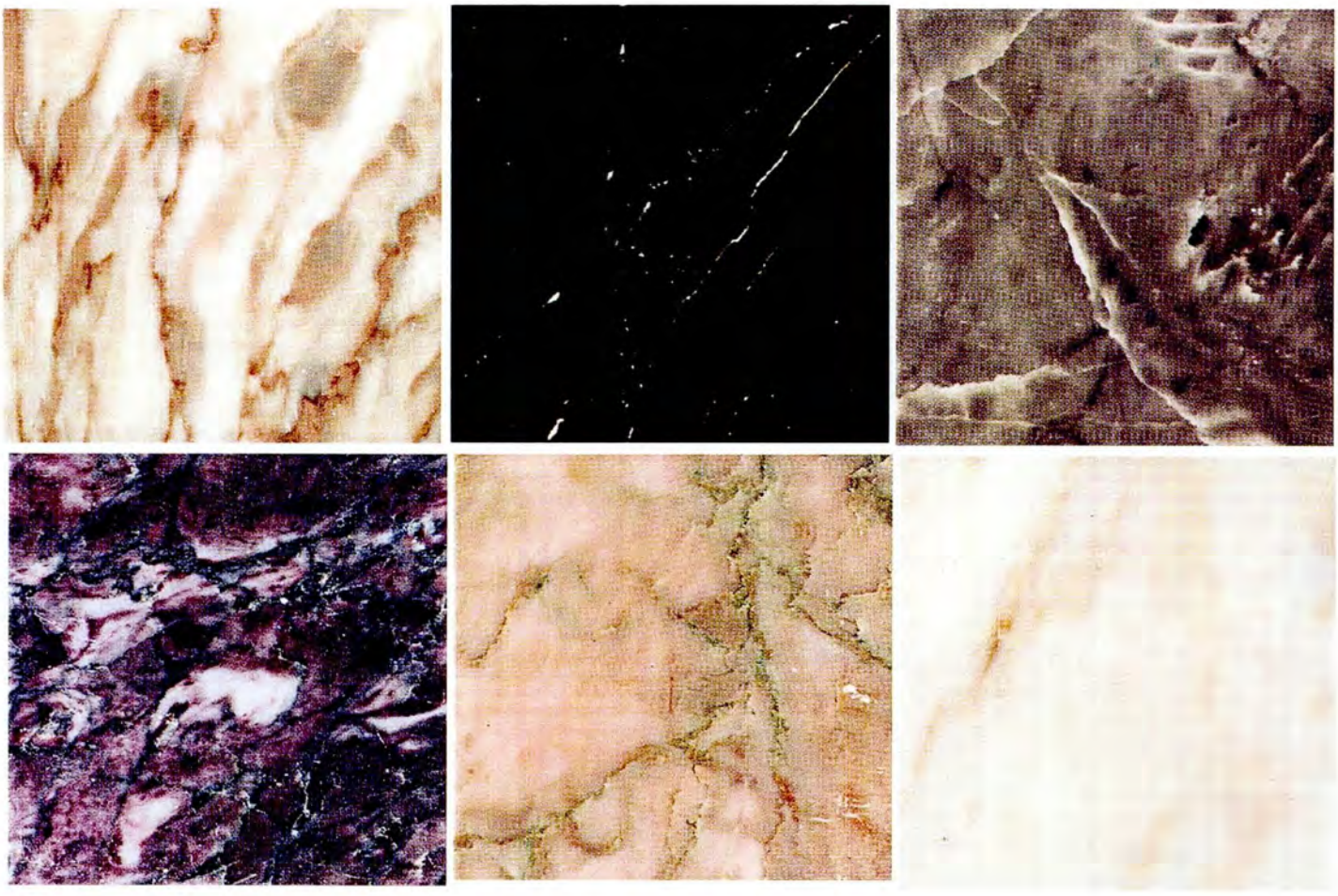


Figure 13
Top of page: variety of marble types produced by Saba Stones from Tigray - Dichinamo quarry.
Above: exhibition of marble tiles, Saba Stone.

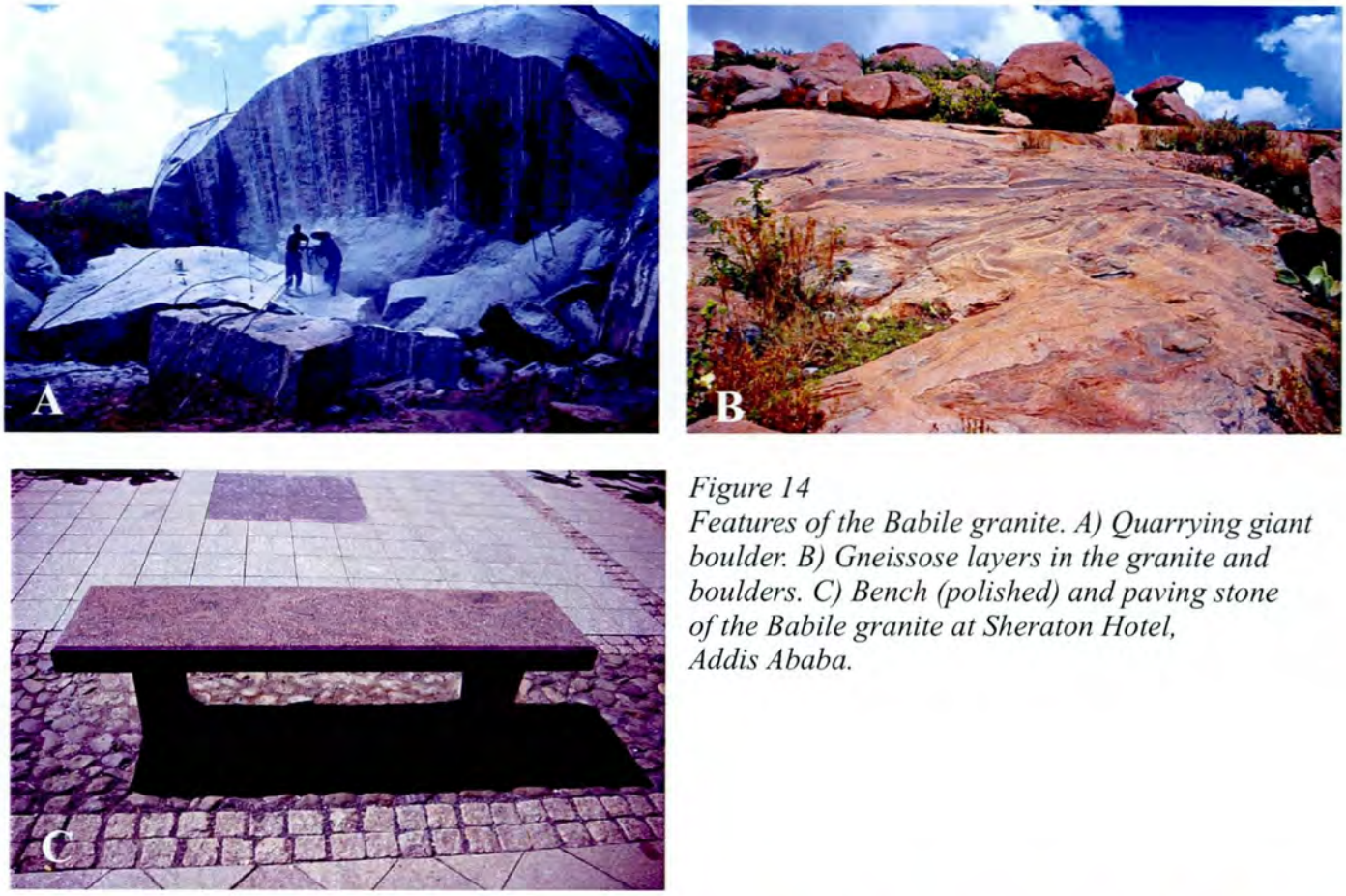


Figure 14
Features of the Babile granite. A) Quarrying giant boulder. B) Gneissose layers in the granite and boulders. C) Bench (polished) and paving stone of the Babile granite at Sheraton Hotel, Addis Ababa.

Figure 15
Polished slab of the Babile granite. Scale 1:1.

GEOLOGICAL MAP OF GUMER AND KUCH AREA WITH GRANITE AND SANDSTONE DEPOSITS

(Geological map from EMEED-Metalic mineral division)

Figure 16

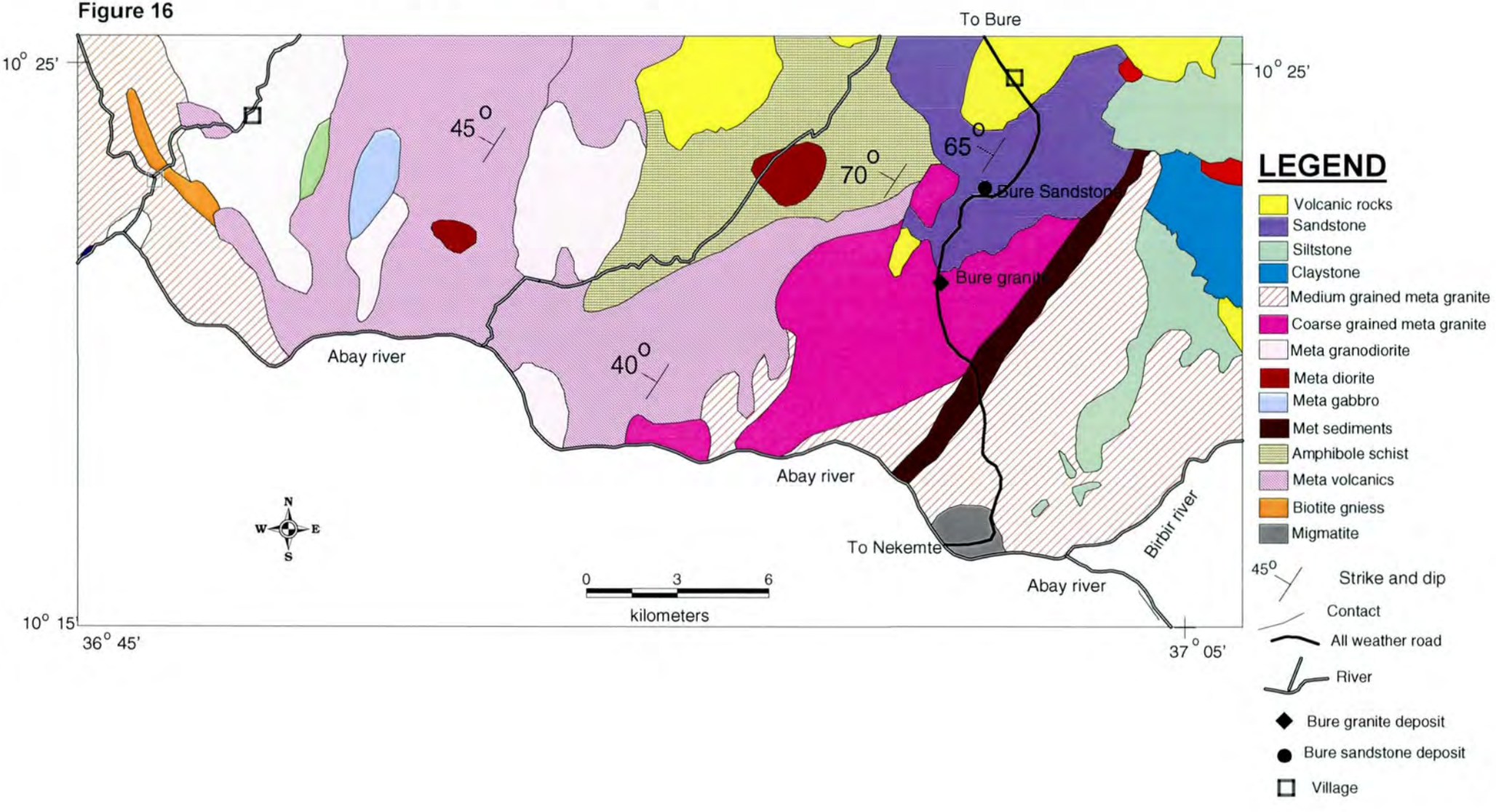


Figure 17
The Bure and the Angerguten granites. A) Granite landscape, Bure. B) Detail of the porphyritic granite in Bure. C) Raw block of the Angerguten granite (perpendicular to foliation). D) Raw blocks waiting for transportation in the Angerguten granite quarry.

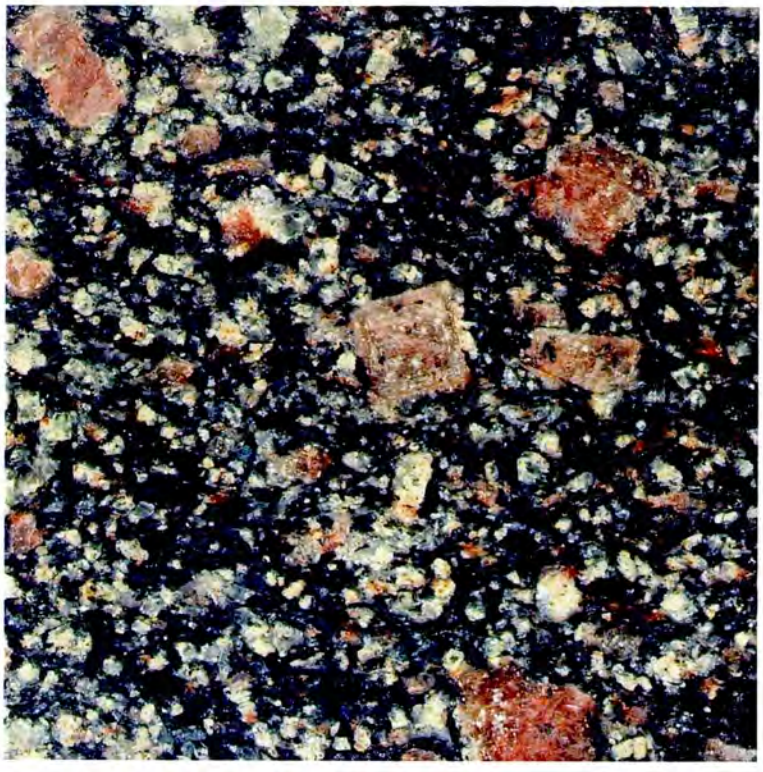


Figure 18
Polished slab of the Angerguten granite. Scale 1:1.
The colours may deviate from the original sample.

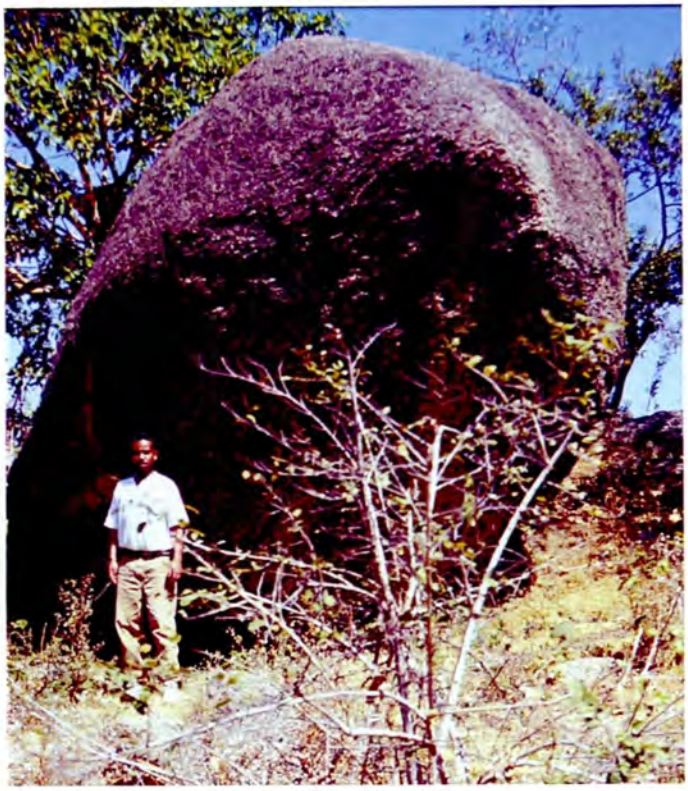


Figure 19
The Dehan granite - boulder.

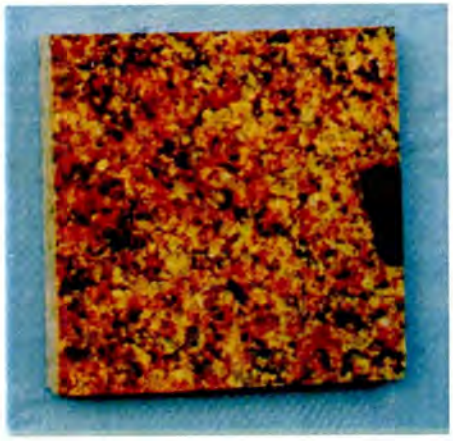


Figure 20
Polished slab of the Dehan granite.

Figure 21
A) Remaining block in the Negash granite quarry.
B) Detail of split granite surface, Negash.

Figure 22
Abandoned pilot quarry in the Meleika area, Sidamo.

Figure 23
Road cut in soapstone deposit in the Kenticha area.

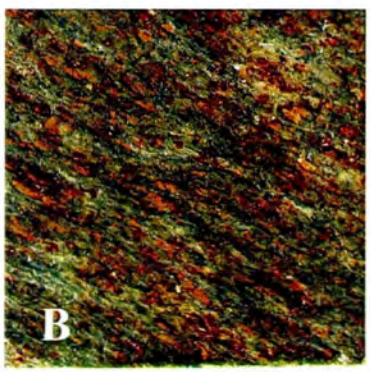


Figure 24
Massive soapstone at Zigi. A) Outcrop. B) Honed slab, scale 1:1. Note: carbonate grains are brownish due to surface weathering.

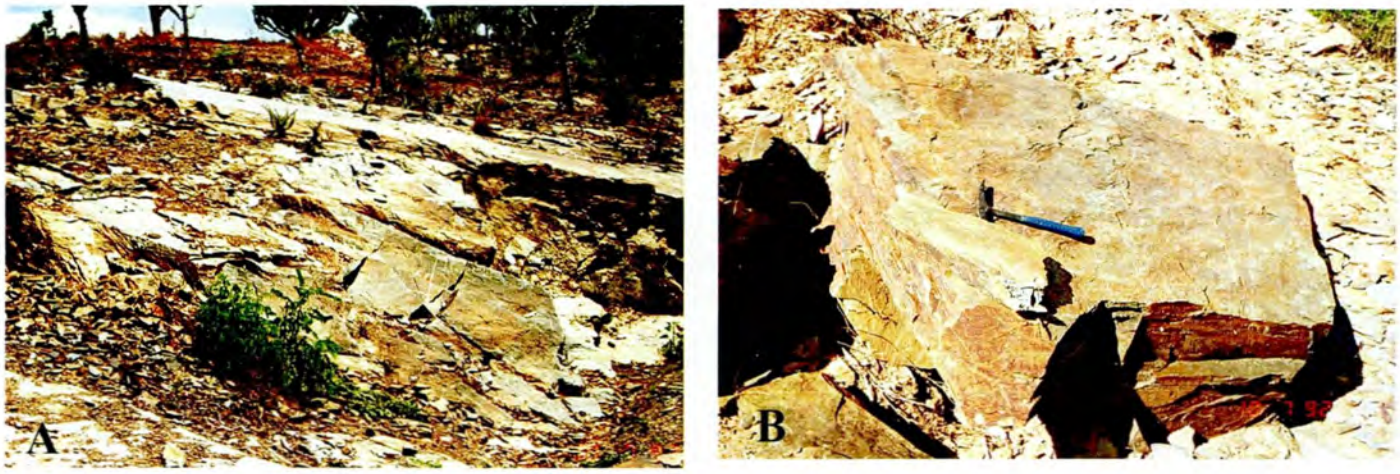


Figure 25
Slate deposit in Tigray. A) Jilajile quarry. B) Detail of block - note irregular surface of cleavage.

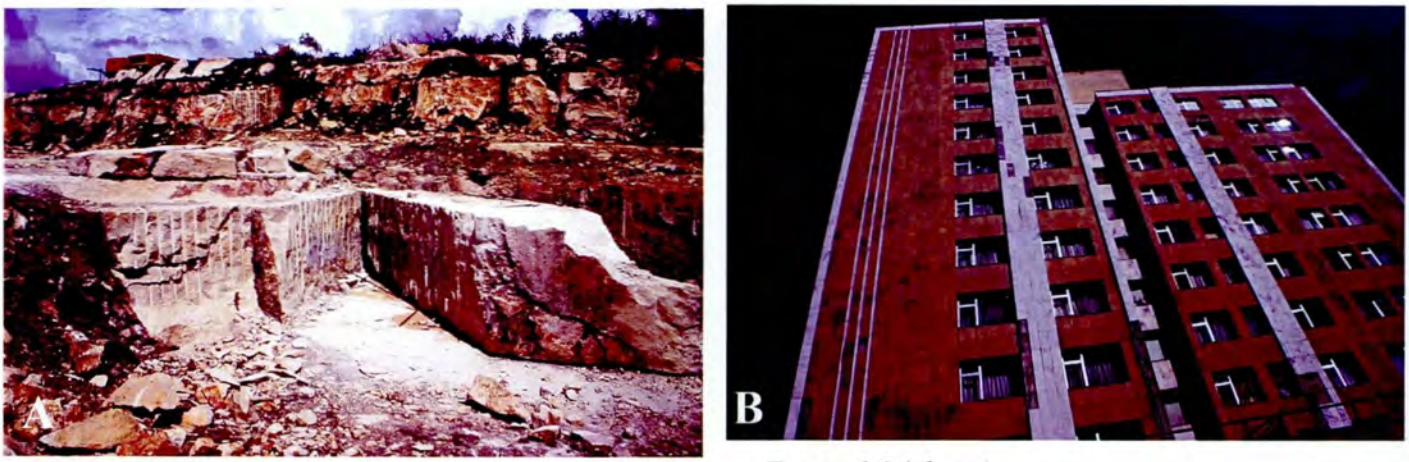


Figure 26 (above)
A) Limestone beds in the Hakimgara quarry, Harar. B) The Hakimgara limestone used as facade cladding in Addis Ababa, combined with stripes of the Daleti marble.

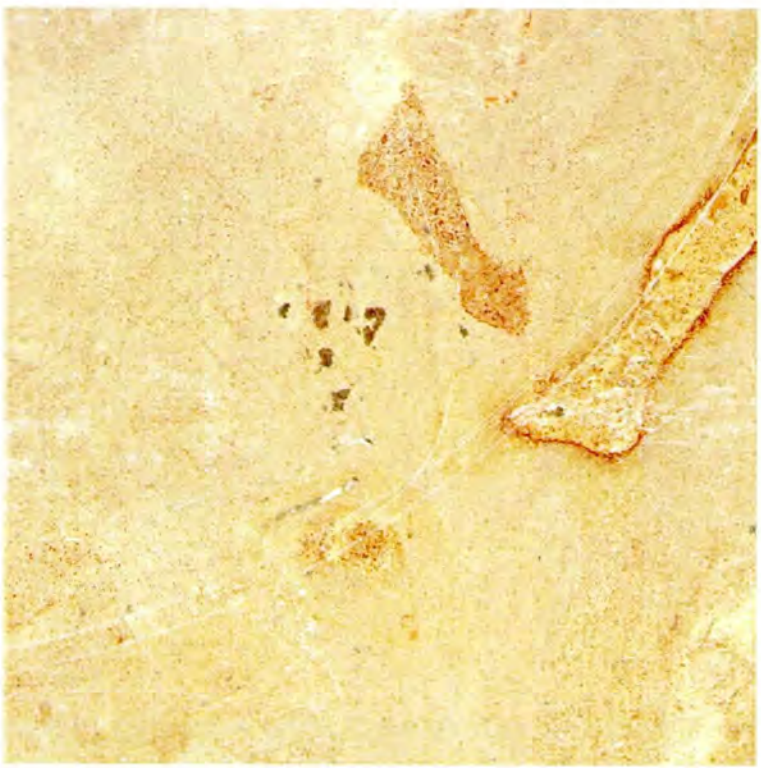


Figure 27 (left)
Polished slab of the Hakimgara limestone. Scale 1:1.
The colour may deviate from the original sample.

Figure 28
The Jema limestone deposit. A) Beds of the lower part of the deposit. B) detail of yellowish limestone.

Figure 29
The Mosobo limestone deposit. A) Limestone beds. B) Remaining blocks in the pilot quarry.

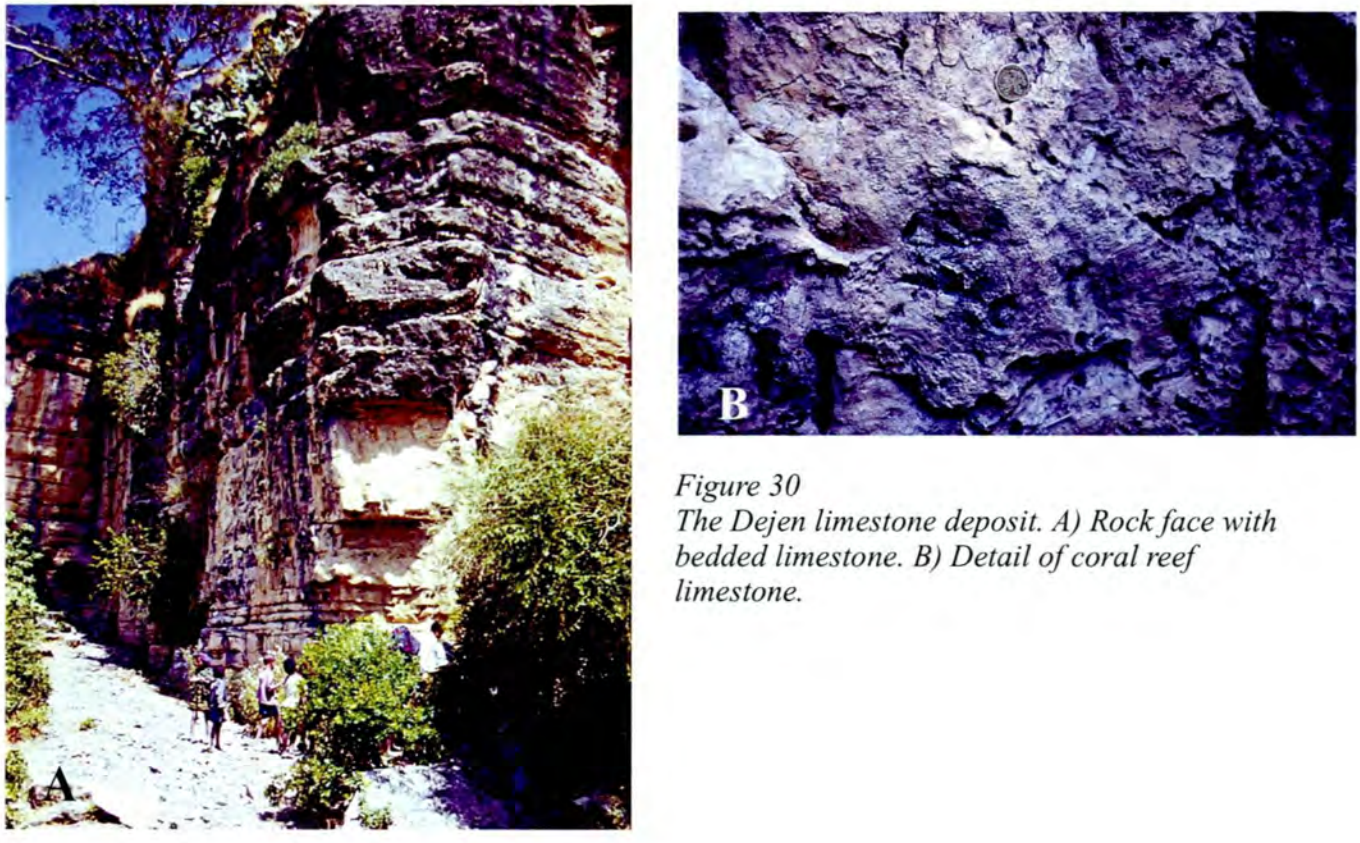


Figure 30
The Dejen limestone deposit. A) Rock face with bedded limestone. B) Detail of coral reef limestone.

Figure 31
The Ambo sandstone. A) Shaping sandstone blocks. B) Quarry. C) Sandstone wall in Addis Ababa.

Figure 32
Cross-bedded sandstone in the Bure area.

Figure 33
Ignimbrite in Addis Ababa. A) Quarrying with sledge and wedges. B) Ignimbrite in the Catholic Church, Addis Ababa. C) Ignimbrite in the Cathedral, Addis Ababa.

Figure 34
A) Quarry in columnar basalt, Ambo. B) Building wall of vesicular basalt.

Appendix 1

Dimension stone deposits and their status

Name	Type	Location		Distance from Addis Ababa	Colour	Grain size, type	Reserves in tons	Block size in tons (Product)	Status	Owner	Application
		Region	Locality								
Mora	Marble	Benishangu	Metekel Mora	595km	Gray to dark gray	Coarse grained, calcitic	$13.58x10^6$	20	Mining	EMI	Building faces, stairs, pavements
Bapuri	Marble	Benishangul	Metekel Mora	600km	Gray	Coarse, calcitic	Thousands	Medium	Mining	Berta	Building faces, stairs, pavements
Bulen	Marble	Benishangul	Metekel Bulen	580km	Black and gray	Fine grained, calcitic	$24.51x10^6$	15	Exploration	_____	Building faces, stairs, tabletops
Tulu Monye	Marble	Benishangul	Metekel Baruda	610km	Black	Fine grained, calcitic	_____	32	Exploration	TAI	Building faces, stairs, pavements
Ekonte	Marble	Benishangul	Metekel Baruda	605km	Light gray to gray	Coarse grained, calcitic	$4.98x10^6$	16	Mining	EMI	Building faces, stairs, pavements
Ganzi	Marble	Benishangul	Metekel Zigi	580km	Gray	Coarse grained, calcitic	_____	_____	Exploration	_____	Building faces, stairs, pavements
Gewi	Marble	Benishangul	Metekel-Baruda	612km	Dark gray	Fine grained, calcitic	Thousands	Large	Exploration	TAI	Building faces, stairs, pavements
Daleti	Marble	Benishangul	Mendi Daleti	635km	Multi colour	Fine-medium grained	Several thousands	20	Mining	NMC	Building faces, pavements, stairs

Name	Type	Location		Distance from Addis Ababa	Colour	Grain size, type	Reserves in tons	Block size in tons (Product)	Status	Owner	Application
		Region	Locality								
Mankush	Marble	Benishangul	Metekel Mankush	705km	Light gray	Coarse grained, calcitic	Several million	25	Mining	EMI and Berta	Building faces, stairs, pavements
Aken	Marble	Benishangul	Metekel Mora	605km	White	Coarse grained, calcitic	Several thousands	Large	Exploration	TAI	Building faces, stairs, pavements
Hamaresa	Granite	Harari	Harar	8km from Harar	Light gray to pink	Coarse grained	_____	_____	Abandoned	ELMICO	Building faces, stairs, pavements
Babile	Granite	Oromia	Harar Babile	5km from Babile	Pink-red	Medium grained	Several thousands	Large	Mining	NMC	Building faces, stairs, pavements
Bure	Granite	Amara	Gojam	350km	Pink	Coarse grained, porphyritic	Several thousands	Large	New deposit	_____	Building faces, stairs, pavements
Anger guten	Granite	Oromia	Wolega	_____	Pink	Coarse grained porphyritic	Several thousands	Large	Mining	NMC	Building faces, stairs, pavements
Dehan	Granite	Oromia	Metekel Dehan	602km	Pink	Coarse grained	Several thousands	Large	Exploration	TAI	Building faces, stairs, pavements
Negash	Granite	Tigray	Negash	755km	Pink	Medium grained	$58.0x10^7m^3$	Large	Abandoned	NMC	Building faces, stairs, pavements
Melika	Granite	Oromia	Sidamo	_____	Pink	Medium grained	_____	_____	Abandoned	NMC	_____

Name	Type	Location		Distance from Addis Ababa	Colour	Grain size, type	Reserves in tons	Block size in tons (Product)	Status	Owner	Application
		Region	Locality								
Zigi	Soapstone	Benishangul	Metekel Zigi	575km	Light gray	Fine grained	_____	_____	Exploration	_____	_____
Kenticha	Soapstone	Oromia	Sidamo	_____	Light gray	Fine grained	_____	_____	_____	_____	_____
Jilajile	Slate	Tigray	Adigrat	5km from Adigrat	Bluish black	Fine grained	Several thousands	_____	New deposit		Roofing, pavements
Hakim gara	Limestone	Hareri	Harar	5km from Harar	Light yellow to gray	Fine grained, calcitic	Several millions	_____	Mining	NMC and EMI	Building faces, stairs, pavements
Delga Chebsi	Limestone	Oromia	Diredawa Shinile	20km from Diredawa	Yellow, red, gray	Fine grained calcitic	_____	Chips	Abandoned quarry	NMC and EMI	Floors
Dejen	Limestone	Amhara	Dejen	225km	Light yellow	Fine grained calcitic	Several thousands	Large	Exploration	_____	Building faces, stairs, pavements
Filiklik	Limestone	Oromia	Gohatsion	190km	Light yellow	Fine grained calcitic	Several thousands	Large	Exploration	TAI	Building faces, stairs, pavements
Mosobo	Limestone	Oromia	Mekele Mosobo	20km from Mekle	Light yellow	Fine grained, calcitic	$9x10^6$	large	Mining	Saba stone	Pavements
Jema & Wonchit	Limestone	Amara	Merehabete	130km	Light gray to creamy	Micro crystalline	Several thousands	_____	Exploration	_____	chips

Name	Type	Location		Distance from Addis Ababa	Colour	Grain size, type	Reserves in tons	Block size in tons (Product)	Status	Owner	Application
		Region	Locality								
Ambo	Sandstone	Oromia	Ambo-Senkele	_____	White, red & yellow	Fine grained	_____	Ashlar	Mining	Cooperatives	Houses and fences
Addis Ababa area	Ignimbrite	Addis Ababa	Addis Ababa	Around Addis Ababa	Gray to light brown	Fine grained	Several million	Rubble	Mining	Different organizations	Houses, fences and roads
Dichinamo	Marble	Tigray	Shiraro Dichinamo	_____	Multi colour	Fine grained, calcitic	$242x10^6$	Large	Mining	Saba stone	Building faces, stairs, tabletops, pavements

TAI = Tis Abay International
NMC = National Mining Company
EMI = Ethiopian Marble Industry
ELMICO=Ethiolibian Mining Company