Building stone of central and southern Ethiopia: deposits and resource potential

HAILEYESUS WALLE, SINTAYEHU ZEWDE & TOM HELDAL

Walle, H., Zewde, S. & Heldal, T. 2000: Building stone of central and southern Ethiopia: deposits and resource potential. *Norges geologiske undersøkelse Bulletin 436*, 175-182.

The bedrock geology of Ethiopia exhibits a variety of rock types that can potentially be developed for building stone production. The ETHIONOR project has so far included investigation of such resources in the southern and central parts of Ethiopia. Within the Precambrian, there are several deposits of pink and grey granitoids, grey and white marble, soapstone and serpentinite; a number of these deposits are currently exploited by Ethiopian companies. Mesozoic sandstone and limestone are found at several places in the east-central and central part of the country, and in addition to the small number of existing quarry operations, a potential exists for the development of new deposits. Basalt, tuffs and ignimbrite are extensively used for local housing and construction in Ethiopia. Such resources represent a potential for low-cost supply of an excellent construction material, and could be developed further.

Haileyesus Walle & Sintayehu Zewde, Ethiopian Institute of Geological Surveys, Addis Ababa, Ethiopia.
Tom Heldal, Norges geologiske undersøkelse, N-7491 Trondheim, Norway.

Introduction

During the last 20 years, the production and use of building stone[1] has steadily increased worldwide, and today stone has reached a position as one of the world's most important mineral resources. For many countries, export of stone has become a significant economic activity. For others, the recognition of local sources of building stone has secured a steady supply of cheap and durable construction materials for domestic purposes.

Almost any type of rock that can be shaped and dressed to blocks and slabs can be considered as a potential building stone source. Most commonly exploited are massive rocks such as granite and other igneous rocks, marble, limestone and sandstone, and slab rocks such as slate and flagstone. For local housing and other construction, soft and/or easily cleaved rocks are preferred, since they can be worked with simple tools. On the international market, however, the aesthetic properties of the rocks (colour and structure) are far more important, and generally the pricing of building stone depends on the exclusiveness of the rock. Rare colours such as blue, pure white, pure black, yellow and emerald green are considerable higher priced than the more 'ordinary' colours. For example, prices (delivered port) for blocks of the low priced varieties of Indian siliceous stone are from 300 to 600 USD/cbm, depending on block size. Similarly, a middle price range is from 600 to 1000 USD/cbm, and high-price types from 1000 to 1400 USD/cbm[2]. For Norwegian 'Blue Pearl' larvikite, the price range is 1000 – 2000 USD/cbm. For any industrial scaled operation on building stone, it is of vital importance that the deposit can give commercial-sized blocks (minimum 220 x 120 x 100 cm) and/or slabs of uniform quality, with production costs matching the market price (Shadmon 1996).

During the last decades, and especially during the 1990's, systematic prospecting for building stone in Ethiopia has been carried out by both the EIGS and private companies, and a number of building stone deposits throughout the country have been put into production. This is reflected by the extensive use of Ethiopian stone in new buildings in the capital and other cities.

Thus, an important goal within the ETHIONOR project[3] is to investigate and evaluate the potential for locating building stone deposits in Ethiopia. So far, fieldwork has been carried out in the central and southern parts of the country, and the main results are presented in this paper. The northern regions of Gonder, Tigray and Amhara will be covered in the remaining part of the project period (1999-2000).

Geological background

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 and include some of the most interesting building stone sources, such as marbles, granitoids and soapstone. Thick successions of Palaeozoic and Mesozoic sediments (25%) overlie the Precambrian. These include building stone quality limestones and sandstones. A large part of the country is covered by Tertiary and Quaternary volcanic rocks (44%), and in these areas, basalts,

1. The term 'building stone' includes any type of rock, shaped and dressed to blocks or slabs, used for construction. Building stone is a more general term than the term 'dimension stone', which is restricted to cut-to-size slabs and blocks.
2. http//www.chariotinternational.com/priceListTiles.htm
3. The ETHIONOR project is an Ethiopian-Norwegian co-operation project aimed at increasing the knowledge of mineral resources in Ethiopia. NGU is advising EIGS within various fields regarding mineral resources exploration and geological mapping.

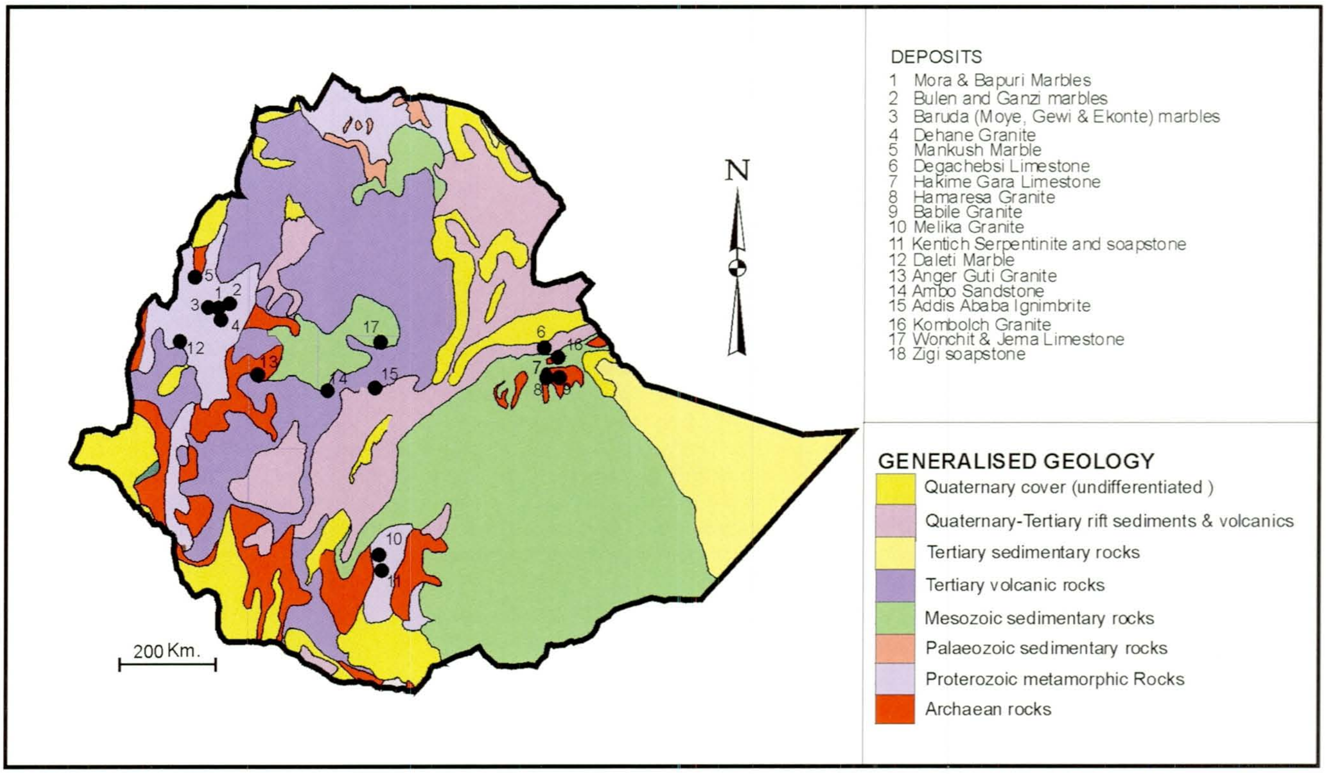

Fig. 1. Simplified geological map of Ethiopia with localities of building stone in the central and southern parts of the country.

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 1972). The Lower Complex comprises possibly Archaean gneisses, migmatites and granitoids, forming a basement to the volcanosedimentary successions of the Middle and Upper Proterozoic Complexes. These successions essentially show polyphase 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 granitoids of Proterozoic to Early Palaeozoic age, occur as intrusive bodies within the Precambrian metamorphic units. Some of these have been emplaced prior to, or contemporaneous with, 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 portion of the Mesozoic succession is represented by the *Adigrat Sandstone* of Triassic to Jurassic age. This rests unconformably on the Precambrian basement, or slightly unconformably on locally developed Palaeozoic sedimentary rocks. The Adigrat sandstone varies in thickness from a few to 800 m, and consists essentially of red to yellow, 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. These vary 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 portion 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.

Massive stone - marble, limestone and granite

In the exploitation of massive stone (dimensional stone), large, commercial blocks are extracted in the quarry and transported to a processing plant for final shaping and finishing to slabs and tiles. The most homogeneous and attractive types of rocks may be exported to other countries as rough blocks. Generally, deposits suitable for exploitation of massive stone should be very homogeneous, both in colour and in structure. Furthermore, the occurrence of joints, veins and other factors that contribute to a reduction in the overall block yield, should be very small, except for extremely high-priced (rare) rocks. The most obvious resource potential within the investigated regions in Ethiopia lies in the huge marble formations in the western part of the country, and in different varieties of granites and gneiss, limestone and serpentinite/soapstone.

Market evaluation of such deposits is difficult. Firstly, there are no objective price lists available on the international market, and prices can vary greatly due to changes of fashion and personal taste of the customers. Secondly, very few producers actually go public with their prices, and a picture of the market situation implies a need for experience among the professionals involved in the evaluation of stone deposits. Furthermore, the market for rough blocks is significantly different in comparison with finished products. In the former case, the customers are stone-producing companies around the world, whilst the customers of finished products are end-users (architects and constructors). The notable difference in raw material prices for different rock types may not be as obvious for finished products. Generally, however, the price difference between highly attractive and less attractive rock types is much higher for raw blocks than for finished products. In this article, we have used published and non-published price lists for raw blocks of comparable types of stone as a tool in market evaluation. Due to the subjective character of such information, price indications given below must be regarded as indicative only.

In Ethiopia, the use and domestic production of cut-to-size stone have increased during the last decades, contributing positively in the development of a high-quality, domestic industry. For the major part, dimension stone used in Ethiopia is derived from domestic sources. Although limestone and marble have been produced for a long time, the production and use of siliceous rocks has only recently started, and

Fig. 2. The Daleti marble (Wellega) cladding the facades of a modern building in Addis Ababa.

it is within that sector we would expect the most significant growth in the country's dimension-stone production in the years to come.

Marble

The most interesting deposits of marble are found in the western part of Wellega (Daleti) and Gojam (Mora, Bulen, Mankush and Baruda). The area is quite remote, and transport distances to Addis Ababa vary between 550 and 800 km, for the most part along non-paved roads. However, at the 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 form an elevated morphology, others have a flat, though well exposed, morphology. Predominantly, the marbles are cal-

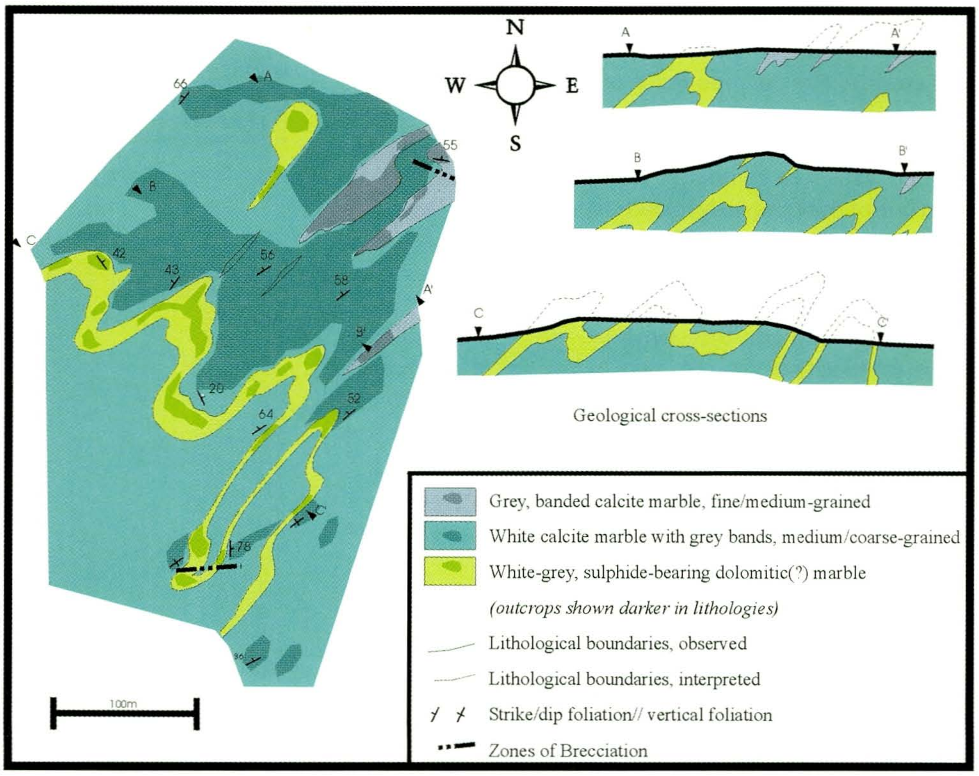

Fig. 3. Detailed geological map of the Ganzi marble deposit, Gojam (see Fig. 1 for location). The map illustrates the structural complexity seen in some of the marble deposits.

Fig. 4. Folded pre-tectonic dykes (amphibolite) in calcite marble, Mankush, Gojam.

citic, but white to grey dolomite occur as layers within the calcite marbles or as bordering units. The latter has, until now, not been of significant interest as building 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 (Fig. 2) 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, both from field observations and comparison with description of similar deposits in Norway, to be connected to contact-metamorphic aureoles surrounding gabbro intrusions. Grain size varies from fine- to coarse-grained, and these variations are believed to be the result of local variations in metamorphic conditions, probably caused by heating related to syntectonic intrusions, and grain-size reduction during later deformation episodes, especially in high-strain zones. In the latter case, 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 interbanded with less competent calcite marble. An example from one of the complexly folded Gojam deposits is shown in Fig. 3. Measurements of fold axes further show that the folds are non-cylindrical, demanding care in estimating subsurface marble reserves.

Pre-, syn- and post-tectonic dykes and veins of acidic and basic composition are common in several of the marble deposits (Fig. 4). 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 EIGS indicate a fairly good potential for increasing the production of low- to medium-priced, grey and white marble from the area. Furthermore, investigations suggest a possible development of highly exclusive types of marble, such as pure white and sky blue varieties. The latter two may obtain very high prices on the international market, but the deposits discovered to date are small and inhomogeneous.

Granitoids and gneiss

Intrusive igneous rocks are common in the Precambrian of Ethiopia and range from granitic bodies within the migmatites of the Lower Complex, to pre-, syn and post-tectonic intrusions in the Middle and Upper Complexes (Kazmin 1972, Heldal et al. 1997). The former group is possibly of Archaean age, and, at present, the National Mining Company is exploiting deposits in the Harar area (Fig. 5). The deposits are situated close to the small town of *Babile*, and form massive boulders and small hills, giving good opportunities for the extraction of large volumes of commercial-sized blocks. The Babile granite is a medium-grained, pink to red 'schlieren'-granite with a variegated, veined structure (Fig. 6), reflecting its close relationships with the surrounding migmatitic gneisses. By comparison with other commercial 'schlieren'-granites on the international market, a low- to medium-price level is estimated. The structure of the granite may vary within small areas between more or less gneissose (Fig 7),

Fig. 5. Quarrying of a giant boulder in the Babile granite deposit, Harar.

Fig. 6. Polished surface of the variegated Babile granite (right) and flamed and honed tiles of the porphyritic Anger Guten granite (left). Hotel Sheraton, Addis Ababa.

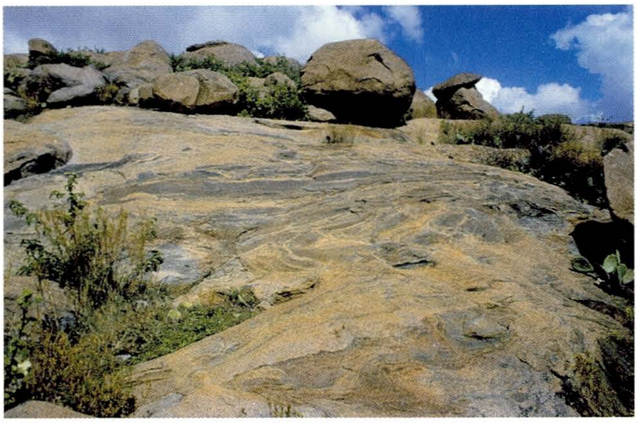

Fig. 7. Gneissose layers in the Babile granite deposit.

giving possibilities for extraction of several commercial stone types, but also demanding care in the prediction of uniform future reserves.

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, all estimated to belong to a low- to medium-price level at the market. The plutons may show a penetrative foliation throughout their entire thickness, or have a foliated margin with a massive, non-foliated core. *The Anger Guti* granite, Wellega (sometimes called the Guten granite), is presently exploited by National Mining Company. This is a foliated 'Augen'-granite, with large, pink phenocrysts of microcline in a brownish-grey groundmass of biotite, plagioclase, quartz and potassium feldspar (Figs. 6 and 8). Several deposits occur in the area, forming smooth hills, with a steep foliation facilitating extraction by drilling, blasting and wedging. Variations in colour and structure may occur, especially due to heterogeneous distribution of the phenocrysts and a varying degree of foliation development. The phenocrysts are commonly rounded and rotated by strain. Aplitic veins of several generations are abundant, and may contribute to an increasing waste ratio in some of the deposits. Joint spacing in the area varies significantly, but some small hills show a spacing of more than 1.5 m on average, which may be sufficient for large block production.

Several other granite deposits may be of future interest. These include the *Dehane granite*, close to Mora in Gojam. This is a coarse-grained, pink granite, forming huge hills and ridges of boulder deposits, which by reconnaissance appear to be very homogeneous in colour and structure. Joints are widely spaced, facilitating production of large blocks. In the south, pilot quarrying of fine-grained, pinkish-grey granite has been carried out near *Kibre Mengist* in the Sidamo area, where several small, syn-tectonic(?) granite plutons occur. However, these granites are tightly jointed, and locally thick kaolin zones are developed in the weathering profile. Thus, these granites are probably not of great interest as dimension-stone prospects.

Limestone

Calcitic limestone of dimension-stone quality is predominantly found within the Jurassic Antalo limestone (central part of the country) 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.

The *Jema* and *Wonchit* limestone deposits occur in the bottoms of the valleys of the same names. The lower part of the limestone unit is by far the most interesting, since this is the part where the bed thickness reaches more than one metre (Wondafresh et al. 1993). The limestone is essentially a calcareaous, fossilifereous sandstone with poorly developed structure; colour varies from brown to off-white. Joint spacing varies considerably in the area, where the more massive parts of the deposits form small hills and plateaux. At the present time, these limestone deposits are not being exploited, due to difficult access (the access road is of poor quality) and locally closely spaced joints.

Large limestone deposits are also found in the eastern part of Ethiopia, in the *Harar-Hakimgara* areas. The Hakimgara limestone has beds varying from some tens of centime-

Fig. 8. Raw block surface of the Anger Guten granite in the quarry (cut perpendicular to the foliation). Drillholes are approximately 25 mm wide.

Fig. 9. Sawn limestone bed in a quarry within the Hakimgara limestone deposit, Harar. Note reduction fields in the upper part of the bed.

tres to several metres in thickness (Schlede et al. 1990; Fig 9). Generally, extraction of commercial-sized blocks is possible in the thicker beds, exceeding one metre in thickness, where the spacing of vertical joints is wide. The limestone is partly fossiliferous, and contains abundant stylolites. The colour varies between yellowish-brown and dark grey, the latter occurring in irregularly distributed reduction patterns. Quarrying operations are carried out by both the National Mining Company and the Ethiopian Marble Industry in the vicinity of Harar. The limestone forms hills and the area is considered to have a large potential for easily accessible deposits.

Fig. 11. Massive and homogeneous soapstone in the Metekel Zigi area, Gojam.

Serpentinite and soapstone

These rocks are found in the Upper Complexes of both the Sidamo and the Gojam areas. Deposits in the Sidamo-Kenticha and in the 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 groups 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 antiquity, and well-known types include several Italian deposits, such as the 'Verde Antique'. Serpentinites predominantly belong to low- to medium-price levels. Soapstones are geologically tightly linked to serpentinites, but are not that well established on the international market. However, such rocks are increasingly used for fireplaces and even as building stone in northern Europe, and there might be a future market development which would favour 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 can be reached concerning sub-surface quality of the serpentinite.

The talc zones 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 coarse-grained, flaky and have a green to grey colour. Both massive and schistose zones are observed, the former concentrated in fold hinge zones along the margins of the serpentinites, as illustrated in Fig. 10. 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. Detrital ultramafics are also described from the Sidamo area, but these deposits have not yet been investigated regarding building stone.

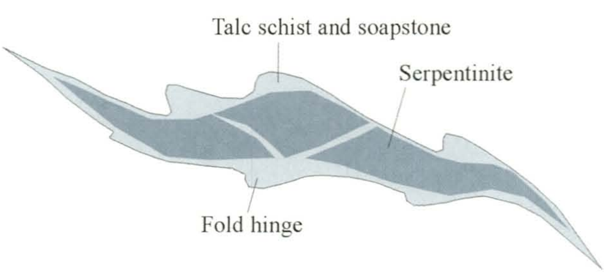

Fig. 10. Sketch showing the occurrence of talc-schist and soapstone enveloping deformed serpentinite bodies in the Kenticha area, Sidamo.

The soapstones in the 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. 11) 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 are necessary, especially concerning the depth of the weathering of magnesite in Kenticha.

Construction stone for local housing

For local housing and construction, easy workable rocks are required in preference to rocks with attractive aesthetic qualities. The stone is shaped and worked to finished products (hewn slabs and building blocks) in the quarry and/or at the construction site. It is important that the rocks can be worked with simple technology to a low cost. In Ethiopia, there are long traditions in using Mesozoic sandstone and tertiary volcanic rocks for such purposes. Also the aforementioned Harar limestone is widely used.

Sandstone

Regarding building stone, the best potential of sandstone lies within the thick, red bed series of the Adigrat Sandstone along an axis from Ambo in the south, through the Abay val-

Fig. 12. Wedging sandstone beds in the Ambo quarries.

leys to Tigray in the north. Exploitation mainly occurs in the deposits near the town of Ambo (Figs. 12 and 13). Here, the cross-bedded, red and white sandstone is worked to ashlars, split bricks and slabs mainly with the help of simple tools such as sledge hammers, wedges and crow bars (Biazen 1962, Heldal et al. 1997). Products are distributed throughout most of Ethiopia, even though a major part of the production is used in the capital.

Fig. 13. Wall cladded with the Ambo sandstone, Hotel Sheraton, Addis Ababa.

Fig. 14. Wall construction with vesicular basalt near Debre Markos.

Basalt, tuff and ignimbrite

Basalt is widely used for local construction, both as building stone and aggregate, in those parts of the country where such rocks are found (Fig. 14). A large number of small basalt quarries are found throughout the Central Highlands, and crudely shaped pieces are worked with simple tools and manpower. In general, the basalt deposits are not considered to be of specific interest for more industrial-scaled building stone exploitation, with the possible exception of columnar and vesicular basalt (Fig. 15). The former could, with simple technology, represent a potential for the production of split paving stone, while the latter, due to its excellent workability, could be used for ashlar and brick.

In and near the Rift Valley, there are sizeable deposits of tuffs (vitric tuff, lithic tuff and crystal tuff) and ignimbrites. These rocks are generally porous, soft to carve and easy to split, and for a long time, ignimbrite and tuff have represented the most important building stones of Addis Ababa (Karstaedt & Wondafrash 1986; Fig. 16). Due to the high porosity, these rocks have excellent insulating properties. A number of small quarries are worked in the vicinity of the capital (Fig. 17), mainly by hand, using simple tools. The ignimbrites are somewhat harder to work than the tuffs, and therefore more commonly used for rubble than ashlars. Due

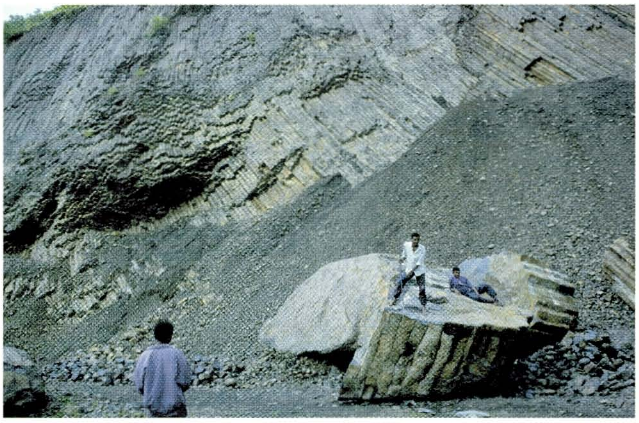

Fig. 15. Quarry in columnar basalt near the town of Ambo.

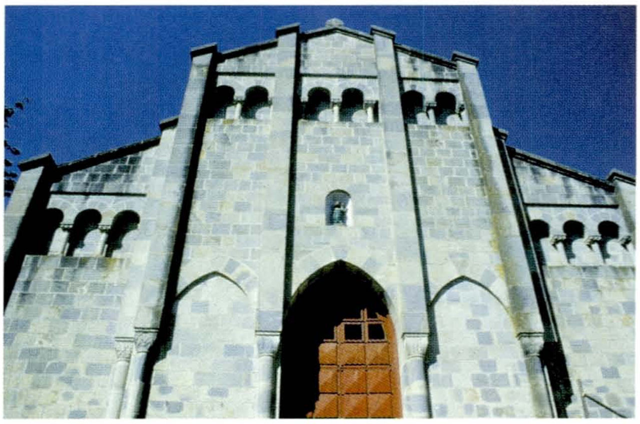

Fig. 16. Ignimbrite used for the construction of the Catholic church in Addis Ababa.

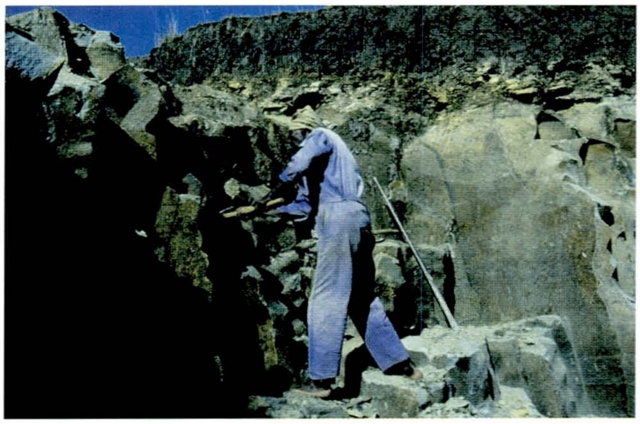

Fig. 17. Ignimbrite quarry in Addis Ababa.

to their softness, such rocks are, however, not very suitable for use as paving stone and stairs.

Tuffs and ignimbrite deposits are also exploited at several other places in the country. For instance, the famous, rock-hewn churches of Lalibela are carved in soft tuffs, and these rocks have also been employed more recently for local construction in the area.

Conclusions

Central and Southern Ethiopia exhibit a variety of rocks that already are either developed as, or can be in the future, 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 homogeneous 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 sector. However, the granitoid deposits localised until now in central and southern Ethiopia are of such a type that will meet tough competition on the international market.

Both limestone and sandstone are extensively used in the domestic market. Within both the Adigrat sandstone and the Antalo and Hamanlei limestones there are still possibilities for exploration of new resources, though these will be limited to the relatively small areas where these units are exposed.

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

Acknowledgements

The authors wish to thank the National Mining Company and Ethiopian Marble Industry for their help during fieldwork. The helpful comments of Ingvar Lindahl (NGU) and Chris Spencer (BRGM, Orleans) are much appreciated.

References

Biazen, B. 1962: Generalized report about the geological view of Ambo and Guder. *Ministry of Mines and State Domain, Addis Ababa, unpublished report.*

Grenne, T., Braathen, A., Selassie, M. G. & Worku, T. 1998: Results and models from fieldwork in the Meso-Neoproterozoic belt of western Ethiopia: the Wombera-Baruda-Bulen-Kilaj transect of the Metekele zone. *Norges geologiske undersøkelse Report 98.110,*

Heldal, T., Haileyesus W. & Sintayehu Z. 1997: Natural Stone in Ethiopia Visited in 1996/97, *Norges geologiske undersøkelse Report 98.040,* .

Karstaedt, H. & Wondafrash, M. 1986: Summarized Report on Building Raw Material in Eastern Addis Ababa (Bole). *Ethiopian Institute of Geological Surveys, Report* (unpublished).

Kazmin, V. 1972: Geology of Ethiopia, Explanatory notes to Geological Map of Ethiopia 1:2,000,000, *Ethiopian Institute of Geological Surveys.*

Malis, E. & Dejene, G. 1983: The Dalati marble deposits. *Ethiopian Institute of Geological Surveys Report* (unpublished).

Mengesh, T., Tadiwos, C. & Workineh, H. 1996: Geological Map of Ethiopia; 1:2,000,000. *Ethiopian Institute of Geological Surveys.*

Mohr, P.A. 1971: *The Geology of Ethiopia*, Hailessilase I University Press, Addis Ababa.

Shadmon, A. 1996: *Stone - an Introduction*, Intermediate Technology Publication, London.

Schlede, H., Walle, H. & Ayalew, S. 1990: Preliminary evaluation of limestone deposits at Delga Chebsi and Hakim Gara (Dire Dawa and East Hararge adm. Region). *Ethiopian Institute of Geological Surveys Report* (unpublished).

Wondafresh, M., Haileyesus, W. & Hailu, B. 1993: Limestone and gypsum resources at Wonchit and Jema Area Merhabete Northern Shoa. *Ethiopian Institute of Geological Surveys Report* (unpublished).