CONTACT METAMORPHISM IN THE UBO AREA, SW NIGERIA

ABSTRACT

The Ubo marble in high grade regional metamorphism (upper amphibolite facies) was intruded in the Precambrian by pre-
to-metamorphic mafic-ultramafic rocks thus giving rise to two distinct metamorphic processes-regional and contact. Owing to low
permeability of a recrystallised upper amphibolite marble, hydrothermal fluid generated by the cooling plutons could not generate
wide reaction isograds except five relatively thin skarn bands in the aureoles around the gabbro and the marble:

(i) calcite – wollastonite
(ii) wollastonite – scapolite – grossularite
(iii) grossularite – andradite
(iv) andradite – diopside
(v) diopside-satellite<handelbergite-plagioclase

The study also revealed that the contact of the intrusives with the marble was at very high level giving rise to vesicular
plugs, pillow piles, basanoids, picritic dykes and ultramafic carpets and flows. The magma got very close to the surface and
partially differentiated into felsic intrusives-granite, aplite and pegmatites which interspersed through the marble generating
calcsilicates of variable sizes and composition.

At the gabbro-marble contact rocks, leucite and mellilitite stabilized at 1035°C and at very low pressures are reported with
XCO₂ and XH₂O ranging from 0.05-0.3% and 0.15-0.32% respectively. These extensive variables represent subvolcanic conditions.
Some chemical ratios TiO₂Al₂O₃, Al₂O₃, Ni/MgO, K₂O/SiO₂, Ba/Rb, Ba/Zr, Th/U, Th/Pb, Zr/Nb, Y/Ni proved to be skarn
discriminants irrespective of the precursor rocks. Two rare elements Pr and Hf were ubiquitous in the sense that they were
found only in the skarn. This suggests that while magmatic fluid was generated unchannelled in the contact aureoles, the source
of some elements could not be attributed to magmatic fluid. Hence some fluid of unknown source was involved in the contact
metamorphism in the Ubo contact aureoles.

KEYWORDS: Hydrothermal, isograds, ultramafic, magmatic, syntectonic

INTRODUCTION

Contact and regional metamorphism have traditionally been separated according to scale and to the
spatial relationship to intrusive heat sources. Contact
metamorphism occurs in aureoles surrounding intrusives while
regional metamorphism is of regional extent with no apparent
relation to heat sources. Kernick (1992) reports that magmatic areas at zones of subduction-continental collision, are usually
characterized by contact metamorphism. Such areas are
typically hosted in rocks of the greenschist and amphibolite
facies of regional metamorphism.

The Ubo marble and the other neighbouring
metasediments are members of the younger metasedimentary
series in the basement complex of southwest Nigeria. The
metasediments in the western half of Nigeria are reported by
several workers to be of greenschist – upper amphibolite

Some syntectonic to pre-tectonic pan, African magmatic
ultramafic plutons intruded the marble bodies massively
making contacts with the marble at several locations. These
rocks, gabbro, picrites, serpentinites basanoids and their
differentiates - granite, aplite and pegmatite dykes also cut
through the marble bodies. Thus the upper-amphibolite
regionally metamorphosed rocks of the Ubo area were
subjected to contact metamorphism in the Precambrian.

The skarn bands developed at the contacts of the
intrusive dykes and plutons with the marble bodies weave a
network within and around the marble bodies.

Kernick (1992) suggested five attributes in the study
of contact metamorphism:

(1) Significant grade changes in metamorphism
over short distance.
(2) Conductive and convective cooling of
intrusives proves important insight into the
thermal history of contact aureoles.
(3) Intrusives provide a source of volatiles – an
evidence for the physicochemical study of
magmatic volatiles.

(4) Contact aureoles are advantageous in that
metamorphism is essentially isobaric.
(5) Belts of regional metamorphism typically
rare evidence of complex tecnothermal
histories with several periods of
metamorphism and deformation.

These five attributes can be envisioned in any contact
aureoles by a combination of these processes and features (i)
coarsening (ii) recrystallization (iii) metasomatization (iv)
anaaxis and (v) deformations.

This work is aimed at:

(i) studying the features at the contact of the
intrusives and the marble bodies so as to
ascertain the characteristic features in
contact aureoles.
(ii) The attendant setting of contact aureoles
under multiphynotic environment.
(iii) The probable processes in the evolution of
contact or hybrid rocks.
(iv) The possible sources of fluids and transport
of fluids and heat energy in affecting contact
reactions.
(v) The resultant textures characteristic of
contact phases.

These systematic steps will go a long way to
distinguish the over emphasized differences between contact
and regional metamorphism.

The Geologic Setting of the marble bodies and the
Intrusive

The Ubo marble and the gneiss like most other
metasediments strike NNE – SSW. Arcelloni (1985) reports
that the marble and the adjacent gneiss to its east have been
disturbed by epirogenesis structurally tilting them 5° east of
North with subsequent dip values 50 – 65°W. It is a wholly
crystalline pure calcium marble body of about a kilometer and
half along the strike and about that same spread in the east-
west direction.
Fig. 1: Geological map of Ubo area. Insert map of Nigeria showing Ubo marble area.
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The intrusive gabbro at its northern border has stopped the marble to a hundred meters above the horizontal plane. The main trunk of the marble is dissected into five or so distinct masses A, B, C, D, E by dolerite dykes (aphyses of the gabbro). Interaction between the dolerites, some felsic dykes (differentiates of the gabbro magma) with the marble produced some narrow banded skarns and celogains (calcisilicates). These hybrids form a network within and round the different marble bodies.

Petrography of the rocks

The Marble Bodies: The Ubo marble is a coarse grained purely calcitic crystalline mass of about 1,500m trending NNW – SSE with stiff dips of (50 – 70°) to the west. It is west of a marginally schist body both of which are parallel to the massive, non-foliated, coarse grained, grayish to leucocratic granitic gneiss body. The marble body has been pycnosected into four units, named (A, B, C and D) by mafic intrusive plugs.

All the marble masses are crystalline, coarse grained. However marble mass A is granoblastic especially, towards the contact with the intrusive, the calcite crystals become much coarser, with rhombs >5cm gradually decreasing in size away from the contact with the gabbro. Different colours and shades of the marble is due to disseminated graphite flakes and oxidized ferrous iron (ferric ions).

The biotite schist body

This is relatively dark, foliated, more or less fissate due to surficial alterations, occurs in oscillatory banding with the marble body at the eastern margin. The scint contains biotite, quartz, K-feldspar and some chloritoid, and andalusite. The layers of the schist were about 10 m thick and gradually thin out towards the west. The schist is also exposed at the contact with the gneiss at a north-south trending channel of River Ubo. The schist is also exposed at the mining trench both in mass A and mass B marble bodies.

The gneiss

The gneiss of the Ubo marble area is a grey, mild leucocratic, slightly banded, less massive metasediment trending NNW – SSE dipping 40 – 60° West and is parallel to the eastwards of the marble body. It is a large body gradually rising from the banks of the Ubo river. Its foliation trend is concordant with strike direction.

The Gabbro/Diorite

The gabbro is a one pyroxene gabbro and contained very high values of CaO (13-20%). It is coarse grained slightly metamorphosed with minorised amphiboles average 10% modal composition in a few samples. [Ashidi (1999 a,b) and Ashidi, 2000]. There was minor olivine reported in the gabbro (Independent mapping exercises). Much stopping and uplifting occur at certain contacts with the marble bodies implying formidable emplacement at such locations. It has the shape of an inheberg – (characteristic concave topped single intrusion common in the basement complex of Nigeria). It has about 50% modal mafic composition that falls in the range of salite-ferrosilite (Ashidi, 2003).

The Ultramafic Rocks

At the northern borders of the major gabbro body lies some stocks about 5-10m high, which have shreds of calcitic plagioclase, pyroxene being the only mineral present. The pyroxene crystals look fibrous and the matrix is slightly foliated which is an evidence of serpentinization. These pillow piles terminate imperceptibly at a basal flow with pyroxene megacrysts (about 8-10cm). The flows go to the base of the plugs and stocks (pillow piles) at certain locations. Within the komatiites some plugs, often elevated to 1-2m, have large vugs and vesicles (2cm) which are termed basanittoids in this work. The magnesium number (N) of the pyroxenes is 85, though the mgo in the main gabbro is in the average slightly less than 80 (Ashidi, 2003).

The Microgranite, Aplite and Pegmatites:

The microgranite and the other felsic rocks (about 2m thick) occur as dykes through the marble. They cut through one another. The microgranite has a lot of mafic minerals biotite and amphiboles. At the contacts with the marble tiny layers of contact effects (skarns) were developed – epidote and zoisite.

The Skarn bodies

Reaction between the marble with silicate phases from the intrusives at the contact between the marble and the plagioclase produce calc-silicate rocks of very narrow bands (<10m). A traverse from the marble across the western contact with the gabbro produced five different isograd bands as follows:

1. Calcite – wollastonite
2. Wollastonite – parawollastonite – Scapolite
3. Scapolite – Tremolite grossularite
5. Andradite – titanite – diopside – plagioclase

Analytical Methods

Sample Preparation and Analysis

All samples preparation and analyses except Fe, CO2 & H2O determinations were carried out at the Departments of Petrography/Mineralogy, and Geochemistry/Geology in the University of Munich, Germany. Analysis of Fe, CO2 and H2O were performed in the University of Belgium.

The preparations include:

i. Thin section slides for transmitted microscopic studies
ii. Polished-thin section of whole rock samples for (SEM) and Microprobe analysis.
iii. Fused glass discs for XRF analysis.
iv. Whole rock digestion for Inductively Coupled Plasma – mass spectrometry (ICP-MS).

Whole-rock dilithium – tetraborate fusion glass discs (iiii above)

0.8g powder of whole rock samples and 4.8g of LiB4O7 were thoroughly mixed and fused at 1,200°C in platinum discs for XRF studies.

Whole rock samples finely ground for acid attack were used in solution for ICP-MS analysis of RHEE values. The polished thin sections were prepared in automatic machine and coated with graphite for microprobe analysis.

The microprobe analysis was done with 15KV, 5nA focused on <1μm area of each sample. Over a hundred whole rock samples were analysed for the geochemical studies.

Several polished thin sections were analysed for plagioclase, pyroxene, amphiboles, scapolite and titanite.

Whole rock samples and single mineral crystals were put for the (XRD) determinations. Philips XRD connected to analytical and recording computers

RESULT OF LABORATORY ANALYSES

Modal Composition

Five mineralogical skarn isograd are established under two major belts: (i) the endoskarn and (ii) exoskarn.

Wollastonite, usually with several fractures, is most often large, columnar or prismatic, poikiloblastic and occur aligned in radiating clusters. A few intergrowths of parawollastonite were identified by higher extinction angles, and by X-R-D identification.

The wollastonite range from 15-30% modal values in 17 out of 38 analysed skarn sections and have average of 20% modal composition. Scapolites are of two forms. They occur as (i) partially altered poikiloclasts and (ii) as primary poikiloblasts. Intense alteration of scapolite yields fibrous scapolite in the exoskarn which is easily taken for
### Table 1: Modal analysis of Skarn minerals.

<table>
<thead>
<tr>
<th>SKARN MODAL ANALYSIS</th>
<th>Gabbro Skarn</th>
<th>Pyroxenite Fe Skarn</th>
<th>Gabbro Skarn</th>
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<tbody>
<tr>
<td><strong>KF+K Feldspar</strong></td>
<td></td>
<td></td>
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<tr>
<td>MODAL-MINE</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>DOPSID</strong></td>
<td>40</td>
<td>20</td>
<td>15</td>
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<tr>
<td>B.C.</td>
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<td></td>
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<tr>
<td><strong>Rutile</strong></td>
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<td>10</td>
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<td>Chlorite-Mica</td>
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<td>70</td>
<td>25</td>
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<tr>
<td>Vesuvianite</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<tr>
<td>Tremolite Actinolite</td>
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<td>10</td>
</tr>
<tr>
<td>Garnet</td>
<td>5</td>
<td>10</td>
<td>5</td>
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<tr>
<td>Wellastonite</td>
<td>15</td>
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<td>10</td>
</tr>
<tr>
<td>Calcite</td>
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<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Epidote</td>
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<td>5</td>
<td>10</td>
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<tr>
<td>B. Quartz</td>
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<td>Zoisite</td>
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<td>Scheelite</td>
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<td>Corundine</td>
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<td>Topazite</td>
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<tr>
<td>Quartz</td>
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<td>5</td>
<td>10</td>
</tr>
<tr>
<td>TiO₂</td>
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<td>5</td>
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### Table 1 continued

<table>
<thead>
<tr>
<th>SKARN MODAL ANALYSIS</th>
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<th>Dolerite Skarn</th>
<th>Gabbro Skarn</th>
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</thead>
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<tr>
<td><strong>KF+K Feldspar</strong></td>
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<td></td>
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<tr>
<td>MODAL-MINE</td>
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<td>3</td>
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<tr>
<td><strong>DOPSID</strong></td>
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<tr>
<td>B.C.</td>
<td>3</td>
<td>13</td>
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<tr>
<td>P. Plagioclase</td>
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<td>Vesuvianite</td>
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<td>Tremolite Act.</td>
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<tr>
<td>Calcite</td>
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<tr>
<td>Epidote</td>
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<td>B. Quartz</td>
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<td>Zoisite</td>
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<td>C. Plagioclase</td>
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<td>Quartz</td>
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<td>TiO₂</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Apate
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fibrolite (fibrous sillimanite) however minute residual calcite crystals still persist inbetween these fibres which distinguish them from fibrolite.

The scapolite poikiloblasts are in two different bands (i) in the endoskarn where it replaces plagioclase (ii) in the exoskarn where it is granoblastic discrete with other skarn minerals. The poikiloblasts had no inclusions of cataclasites like in the ppyrohydroclasts. Their total average modal composition was 25% in the sections in which it was reported. Garnets (anzidride) (25% modal composition) occur as distinct crystals only in the endoskarn, in the exoskarn garnet was anastomosing along the grain edges of ppyrohydroclasts. Vesuvianite has similar form of occurrence and development with that of garnet though it is not observed in the exoskarn.

The neocrystallites within the garnet then have the following characteristics:

(i) linear orientation of crystals (alignment)
(ii) undulose extinction of the crystals
(iii) curved or bent outline of larger zoisite grains
(iv) exsolved calcite shreds.

Primary tremolite-actinolite zoisite and chinozoisite occur as cracked and healed poikiloblasts with growth of calcite and quartz inclusions. Tremolite sheaves, with a lot of inclusions, in most cases, are calcite, quartz, epidote and zoisite. In the calcite-qtz symplectites, quartz grains are tiny, wormlike, sparsely distributed through the calcite matrix. No wollastonite yielded from such intergrowths.

Cordierite has two distinct forms of occurrence, characterized by two different sizes. Garnet crystals besides cordierite hosted small anhedral crystals of the latter as inclusions. Residual cordierite fragments not netted by ppyrohydroclastic garnets occur as subhedral medium sized hexagonal prisms by the sides of large and older grains. Opaques are closely associated with cordierite crystals.

Calcicarbonate and aluminosilicates characterize the hybrid rocks (hornfells - zoisite, vesuvianite-lime-garnet and biotite in contact with cordierite was partially altered to stauroite. Sillimanite in contact with stauroite produces cordierite. Bulbous symplectites developed from intergrowth of quartz with cordierite.

Table 2: Temperature pressure and fluid condition of contact metamorphic assemblages

<table>
<thead>
<tr>
<th>Mineral assemblage</th>
<th>Temp. range °C</th>
<th>Pressure</th>
<th>H2O/CO2</th>
<th>Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cal + Qt + Wn + f(CO2)</td>
<td>600-840</td>
<td>0.1-0.4</td>
<td>Motyoshi et al. 1992</td>
<td></td>
</tr>
<tr>
<td></td>
<td>550-1,400</td>
<td>10-18kbar</td>
<td>Hasselton et al. 1978</td>
<td></td>
</tr>
<tr>
<td></td>
<td>550-750</td>
<td>3kb</td>
<td>Greenwood 1967</td>
<td></td>
</tr>
<tr>
<td></td>
<td>450-550</td>
<td>1-2kb</td>
<td>Zieglarin &amp; Johannes 1981</td>
<td></td>
</tr>
<tr>
<td></td>
<td>550-780</td>
<td>2-3kb</td>
<td>Jacobs &amp; Kempe 1981</td>
<td></td>
</tr>
<tr>
<td></td>
<td>780-800</td>
<td>0.8</td>
<td>Schenk 1984</td>
<td></td>
</tr>
<tr>
<td></td>
<td>780°C</td>
<td>0.0-0.05</td>
<td>Schenk 1984</td>
<td></td>
</tr>
<tr>
<td>2. San = Ca = mabonite BAb + 2Na = marioite</td>
<td>500-650</td>
<td>0.0-0.35</td>
<td>Gordon and Greenwood 1971</td>
<td></td>
</tr>
<tr>
<td>3. An + 2Cal + Qt = Gr + CO2</td>
<td>500-650</td>
<td>1-2kbar</td>
<td>Harschek 1974</td>
<td></td>
</tr>
<tr>
<td>An + 2W + Grua W + Cal = An + Gr + CO2</td>
<td>600-800</td>
<td>1-5.9</td>
<td>Shumakovitch 1978</td>
<td></td>
</tr>
<tr>
<td>4. Tr + Cal + Qt + Di + CO2 + H2O</td>
<td>0.1-0.05</td>
<td>Schenk 1984</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In a prograde equilibrium reactions, the observed phases are formed by the following chemical reactions:

(i) wollastonite: Ca1 + Qtz = WOl + CO2-R1
(ii) scapolite: 3An + Cal = Meionite - R1a
(iii) Garnet: An + 2Cal + Qtz = Gr + 2CO2, An + 2 WOl = Gross. R3a Wo + Cal + An = Gr + CO2; Hed + Qtz = And R3m
(iv) Epidote: Cal + 3An + H2O = Zoept + CO2 R4b Scap + Water = Epi + CO2 (Retrograde) R4b
Zoisite: Cal + 3An + Wat = 2Zois + CO2 R3
Temolite: 5Dol + 8Qtz + H2O = tre - 3Cal + 7CO2 R3
Vesuvianite: Scap + H2O = vesuvianite + CO2 + O2 R7a
Scapolite = Vesuvianite + Cal. R7a
Diopside: Tre + Cal + Qtz = Diop R8
Titanite: 2 Rutile + 3An + Cal + 2Qtz = 2Titanite + Scap. R9
Andalusite: Musc + Qtz = K.Fsp + and + H2O R11
Sillimanite: andalusite = sillimanite R12a
Staurolite + Musc + Qtz = Sil + gar + iot + H2O R12b
Staurolite: Chlorite + muscovite + garnet = staur + bio + Qtz + H2O. R13
Chloritoid: St + Sil + gt = Chloritoid R14
Cordierite: Bio + Mus + Qtz = K-Fsp + Cord. + Ilm + H2O R15

The reactions R1 - R15 are marble related and occurred either at the exoskarn or endoskarn. In both zones decarbonation took place. In reactions R1-R15, water was produced as a result of dehydration. These reactions are more related to the schistose hornfelses. Rice and Ferry (1982), Ferry (1982a, b) Ferry (1983, 1989), Symmes and Ferry (1991) all subscribe to the fact that at least during the low grade stage of either regional or contact metamorphism, a third phase is required. That this third phase is essential for the reactions R1-R15 otherwise carbonate minerals will persist. A fluid phase is considered a general driving force for metamorphic reactions.

Fig. 1 is a composite diagram consisting of two integral parts (a and b). The part a (up) is after Motoyoshi (1992), and Schenk (1984). The 1st part (a) of the diagram is a T-XCO2 diagram illustrating reaction curve in the system CaO - Al2O3 - SiO2 - CO2 - H2O at isobaric Pf = 6kbar. CO2 ranges between 0.05 - 0.5. The 2nd part (b) is the H2O and CO2 values of samples along a major traverse between the marble mass A and the gabbro. The vertical axis of section b represents sample numbers. The graphs of both CO2 and H2O rise from very low values at the intrusive end to much higher values towards the marble. The CO2 values seem complimentary to those of H2O until the point where the skarn is most conspicuous. At this point the value of CO2 rose suddenly above the value of H2O. Symmes and Ferry (1991) reported that the volume of fluid in contact with the rock increase dramatically as decarbonation and dehydration reaction proceed.

Although the isobaric Pf = 6kbar is assumed to simulate a mid-crustal level of equilibrium reactions, it is more or less an hydrostatic state which implies, Pfdat = Pf. If that situation is applied to the Ubo marble area it would only suggest multifractured or sheared regional rock (marble in the study case). No evidence of such multifracturing or shearing was found in the Ubo area. However, Symmes and Ferry (1991) were very optimistic that results of equilibrium assemblages determined under different and various pressure conditions were similar to one another. This implies the factor of high fluid pressure or thickness of overburden in the zone of contact metamorphism is insignificant. The situation in which the isograds of the skarn are relatively narrow in the Ubo area calls for two factors of consideration:

(i) the upper amphibole grade of the regional metamorphic terrane prior to intrusion of the gabbroic plutons.
(ii) the low permeability of the Ubo marble.

Marbles are considered the least permeable of the country rocks reported (including calc-gneiss, H2O - CO2 0.01 - 0.05 gneisses, schists, quartzites and other felsic rocks (Brenan,
However, the HCOO-CO$_3$ (0.01-0.05) values reported for the project samples are in striking similarities of values determined in Shay (1975), Joesten (1976), Ferry (1987), Rice and Ferry (1991) and Ferry (1992). This implies a reliability of the results determined. Though the skarn assemblage in particular is marked with a lot of symplectites of all sorts and mineral intergrowths detectable at the microscope level. The various intergrowths are evidence of either retrograde reactions or reduced pressure due to uplift or increased pressure due to crustal thickening or even due to additional advective heat energy from late intrusive bodies. For a comprehensive basic and thermal regimes, thermophysical conditions of mineral equilibration at the different reaction centers are related to Berman (1987).

- Figure 3. and table 2 is the illustration of the mineral equilibria and the temperatures and pressures ranges at which equilibria are attained. Joesten (1976) reported the occurrence of meionite, rankinite, sparrite, tilyeite and wollastonite at 600°C-1035°C, with XCO$_2$ between 0.2 - 0.6 in high temperature contact metamorphism of carbonate rocks, at Christmas mountain, Texas. The temperature of melilitite and merwinite = 1035°C approaches the solidus of the intrusive magma.

The Ubo marble like the Christmas mountain was intruded by a gabbro and consist of larinite (Ashidi, 2000) and parawollastonite wollastonite/parawollastonite intergrowth and other skarn minerals.

Moreover and however, other parameters-trace element distribution and behaviours of rare earths element contribute towards an accurate assessment of the roles of fluid and heat in whatever way they are being transferred or transmitted.

The characteristic distribution of trace elements in the precursor rocks surrounding the skarns is strongly biased as found in the skarns. From the trace element partitioning into the different rock types in the contact area, some particular trace elements or their ratios are very reliable discrimination.

### Table 3. Trace Element ratios in the rocks

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Gabbro</th>
<th>Skarn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>28</td>
</tr>
<tr>
<td>K/Rb</td>
<td>476</td>
<td>409</td>
</tr>
<tr>
<td>Rb/Sr</td>
<td>0.01</td>
<td>0</td>
</tr>
<tr>
<td>K/Ba</td>
<td>13.8</td>
<td>10.15</td>
</tr>
<tr>
<td>Ba/Sr</td>
<td>0.25</td>
<td>0.4</td>
</tr>
<tr>
<td>Ca/Sr</td>
<td>141</td>
<td>240</td>
</tr>
<tr>
<td>Rb/Ba</td>
<td>0.03</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table 3 continued trace element ratios in the rocks

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Dol</th>
<th>Skarn</th>
<th>Gabbro</th>
<th>Skarn</th>
<th>Horn</th>
<th>Fels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>71</td>
<td>74</td>
<td>75</td>
<td>90</td>
<td>127</td>
<td>137</td>
</tr>
<tr>
<td>K/Rb</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>Rb/Sr</td>
<td>0.02</td>
<td>0.02</td>
<td>6.93</td>
<td>0.01</td>
<td>0.02</td>
<td>0</td>
</tr>
<tr>
<td>K/Ba</td>
<td>599</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14.7</td>
<td>14.7</td>
</tr>
<tr>
<td>Ba/Sr</td>
<td>0.25</td>
<td>-</td>
<td>17.4</td>
<td>0.08</td>
<td>0.3</td>
<td>0.09</td>
</tr>
<tr>
<td>Ca/Sr</td>
<td>554</td>
<td>352.9</td>
<td>3522</td>
<td>108.91</td>
<td>94.7</td>
<td>150</td>
</tr>
<tr>
<td>Rb/Ba</td>
<td>0.95</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.07</td>
<td>0.03</td>
</tr>
</tbody>
</table>
tools useful in distinguishing a skarn assemblage - either feticiclastic intrusive phases or even metamorphic rocks TiO₂Al₂O₃ AIAO₃ N₂Mg K₂O₃S₂ Ba₂Rb₂ Ba₂Zr TiU. Th/Pb Zr/Nb Y/YNb all show linear relations in the skarns but not so with the mafic and felsic intrusive, K/Rb, Sr/Y have similar trends in both skarn types and the intrusive but relatively higher slopes are recorded in the skarns. Pr. and Ho are detected more or less only in the skarns while Ce, Pr Eu and Sm are enriched in the skarns at the expense of the precursor rocks.

Auvera and Andre (1991) reported a similar trend in which the different types of skarns were enriched in the REE's. The authors suggested that the REE patterns suggest that different types of skarn result from the interaction between the same fluid and different types of original rocks, and that the determinant parameter controlling the repartition of trace elements between fluid and rocks seems to be the Water-Rock (W/R) ratio and not the equilibrium distribution factor.

Bickle and Kenzie (1987) slightly differ in their report that the time scale for advective or diffusive transport of any atomic species is inversely proportional to the partition coefficient of species between solid and fluid. While that assumption may be correct to a reasonable level, it is not likely that in the Ubo case, where most elements were depleted in most isograds of the skarn apart of which it is difficult to assume anaxesis where a fluid phase could be distinct from a crystalized separate phase. One may on the strength of available evidence from this work question the sources of Pr and Ho to suggest a non-magnetic, non-hydrothermal fluid probably buffered that infiltrated the skarn bodies. While on their individual bases the trace elements and REE's were reported by Lummen and Verkoren (1986), the heavy rare earths (HREE) and SiO₂ Al₂O₃ FeO TiO₂ and most of the trace elements were reported to remain constant, Na₂O, RB, Sr, Ba and the light rare earth (LREE) contents are reduced. It is true for most individual elements, but the distribution ratios of certain elements become distinctly characteristic. At level west, a fluid from a source not connected with the formation of the precursor rocks has been involved in the stabilization of the skarn rocks.

CONCLUSION

The roles played by an intrusive body as the source of heat energy that effect coarser crystallization of calcite grain closest to it and that the grain size become progressively smaller away from the intrusive body and that heat close to the subsolidus temperature are involved in the production of larnite and parawollastonite are characteristic features of a contact metamorphic terrane. The heat content generated by advection away from the pluton enabled dehydration and decarbonation progressive reactions that gave rise to five isograds of calcite - wollastonite, wollastonite - scapolite, scapolite - grossular garnet, grossular - andradite - garnet - dicepide - diopside - titane - plagoclase isograds in the Ubo area.

A few minerals are formed in the course of retrograde processes with characteristic symplectic textures and coronas. While many workers subscribe to a magmatic source of an infiltrating magmatic fluid, others point at meteoric or even metamorphic source for the fluid, and several others point to very high pressure conditions. This work is convening the fact that the infiltrating fluid does not necessarily need to be magmatic and at the level of the marble body which was intruded by the gabbro, very low bar conditions, were involved in the metamorphic processes A pervasive fluid flow could have not been probable considering the thickness of the skarn widths which were limited by the low permeability of the country rock that inhibited any timing of fluid with no possibility of being channeled.

REFERENCES


Ashidi, F.U., 2000. Petrology and Geochemistry of the rocks around the Ubo marble in the Igarra Schist belt of Southwest Nig. (Unpubl.) Ph.D Thesis of the University of Benin.


