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CONTACT METAMORPHISM IN THE UBO AREA, SW NIGERIA

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ABSTRACT

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

(i) calcite – wollastonite
(ii) wollastonite – scapolite – grossularite
(iii) grossularite – andradite
(iv) andradite – diopside
(v) diopside-salite-hedenbergite-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, basanitoids, 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, larnite and mellilite stabilized at 1035oC and at very low pressures are reported with XCO_2 and XH_2O ranging from 0.05-0.3% and 0.15-0.32% respectively. These extensive variables represent subvolcanic conditions. Some chemical ratios TiO_2/Al_2O_3. Al/Al_2O_3, Ni/MgO, K_2O/SiO_2, Ba/Rb, Ba/Zr, Th/U, Th/Pb, Zr/Nb, Y/Nb proved to be skarn discriminants irrespective of the precursor rocks. Two rare elements Pr and Ho were ubiquitous in the sense that they were found only in the skarns. This suggests that while magmatic fluid was generated unchannelized 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. Kerrick (1992) reports that magmatic areas at zones of 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 grades of regional metamorphism Odeyemi (1976, 1988).

Some syntectonic to pretectonic pan_African mafic-ultramafic plutons intruded the marble bodies massively making contacts with the marble at several locations. These rocks, gabbro, picrites, serpentinites basanitoids 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.

Thin 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.

Kerrick (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 physiochemical study of magmatic volatiles.
(4) Contact aureoles are advantageous in that metamorphism is essentially isobaric.
(5) Belts of regional metamorphism typically have evidence of complex tectonothermal 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) neocrystallization (iii) metasomatism (iv) anatexis 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 multiplutonic 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 (1965) 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 calcitic marble body of about a kilometer and half along the strike and about that same spread in the east-west direction.

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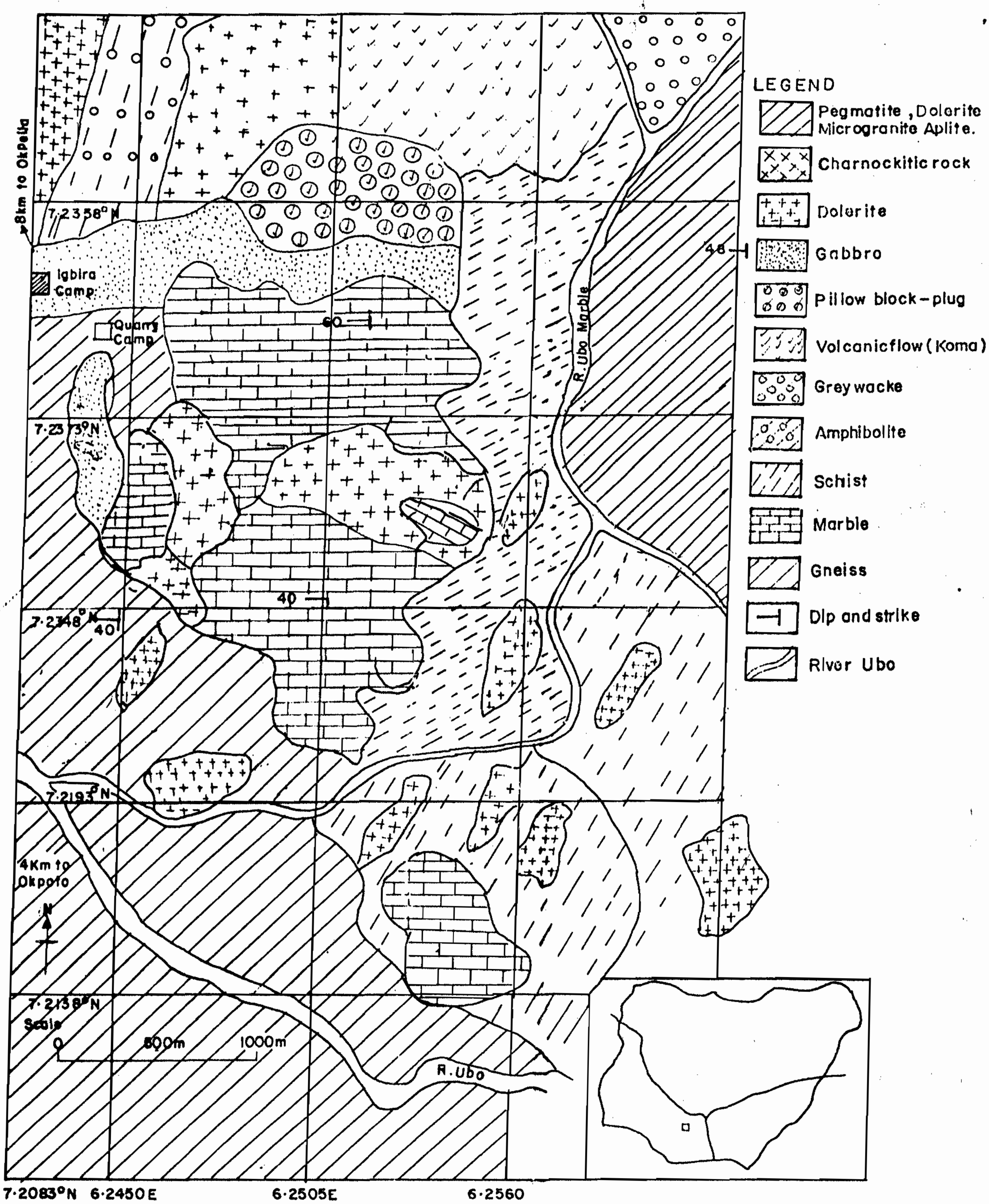

Fig.1: Geological map of Ubo area. Insert map of Nigeria showing Ubo marble area.

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 (apophyses of the gabbro). Interaction between the dolerites, some felsic dykes (differentiates of the gabbro magma) with the marble produced some narrow banded skarns and calcgneiss (calcsilicates). 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 (60 – 70°) to the west. It is west of a marginal 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 ploysected 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 fissile due to surficial alterations, occurs in oscillatory banding with the marble body at the eastern margin. The scist contains biotite, quartz, K-feldspar and some chloritoid, and andalusite. The layers of the schist were about 10 m thick and gradually thins 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, mildy leucocratic, slightly banded, less massive metasediment trending NNW – SSE dipping 40 – 60° West and is parallel to but 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 martitised 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 stoping and uplifting occur at certain contacts with the marble bodies implying forcible emplacement at such locations. It has the shape of an inselberg – (characteristic conic topped single intrusion common in the basement complex of Nigeria). It has about 50% modal mafic composition that falls in the range of salite-ferrosalite (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 basalt flow with pyroxene megracryst (about 8-10cm). The flows got 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 basanitoids in this work. The magnesium number (N) of the pyroxenes is 85, though the mgno 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 plutons 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
4. Grossularite – andradite – titanite – dipside
5. Andradite – titanite – diopside – plagioclase

Analytical Methods

Sample Preparation and Analysis

All samples preparation and analyses except Fe^{3+}, CO_2 & H_2O determinations were carried out at the Departments of Petrography/Mineralogy; and Geochemistry/Geology in the University of Munich, Germany. Analysis of Fe^{3+} CO_2 and H_2O 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 XRFS analysis.
iv. Whole rock digestion for Inductively Coupled Plasma – mass spectrometry. (ICP-MS).

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

0.8g powder of whole rock samples and 4.8g of Li2B4O7 were thoroughly mixed and fused at 1,200°C in platinum discs for XRFS studies.

Whole rock samples finely ground for acid attack were used in solution for ICP-MS analysis of REE 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 ground for the (XRD) determinations. Philips XRD connected to analytical and recording computers.

RESULT OF LABORATORY ANALYSES

Modal Composition

Five mineralogical skarn isograds 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 atimes 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 porphyroclasts and (ii) as fresh primary poikiloblasts. Intense alteration of scapolite yields fibrous scapolite in the exoskarn which is easily taken for

Table 1 : Modal analysis of Skarn minerals.

SKARN MODAL ANALYSIS	4	6	7	9	10	13	14	17	19	20	30	51	52	53	54		
KF=K-Feldspa		Gabbro Skarn				Pyroxenite Fe Skarn	Gb		Gabbro Skarn								
MODAL/MINE	1	2	3	4	5	6	7	8	9	10	11	12		14	15	16	
DIOPSIDE		40		20	15	60	45	20	15		10	10	20		10	10	
SALITE/FAL	5		10	10	10		15		45		35				10		
Hornblende		5						10		10		5					
Plaggiodace				5		5	5	10				5			20		
Scapolite		10	70	25	20	5	20	30	5	10		10	30		20	20	10
Versvvianite											20						
Tremolite Actinolite								20						5		10	
Gernet			5	10	15	5	10		10		20				20	30	20
Wollasitonite		15						30		25				10	10	30	
Calcite		5		5	20	5.	5		5	5	10		15		5	10	20
Epidote		10	5	10	5			10									
B-Quartz										5			20				
Zoisite																	
Scheelite									10			10	10		10	10	10
Corrclinte																	
Tourmaline										5		5					
Quartz		5	5	5	5	5	5	5	5		10		5		5	5	
Titante		20		10	10	5	10		10	10	5	10					
Apatite										10		10					

Table 1 contined

SKARN MODAL ANALYSIS	55	57	59	62	63	64	66	71	74	75	76	77	81	82	83	84	85	86	87	88	89	90	141	147	148
KF = K-Felspar			Pyroxenite Skarn			Dorerite Skarn					Gabbro Skarn														
MODA/MINE	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38			
DIOPSIDE	10	30	20						10		20		20	30	20	20					5				
SALITE/FAL	5	15	20		40																				
Hornblende																									
Plaggiodace		40	30	5	5	40	65					10	10		10	20						5			
Scapolite	70			35				50	20	35	10	30	20		10	10	45	30	50	50	20	40			
Versvvianite											20			20											
Tremolite Actinolite											10	10													
Gernet	20		10	15	20	20	10	10	15	20	20		30	10	50	20	20	20	15	15		5			
Wollasitonite		15	5	30	20			20	30	30		20+chl			10		20		20						
Calcite				5	10			10	5	10								20	20	10	40	10			
Epidote				10				10										20	20	10	40	10			
B-Quartz						15										10									
Zosite	5													40											
Scheelite									20		20	20	30			20									
Corrcliente																						20			
Tourmaline																									
Quartz	20	5				5	5				5		10				5				20	5			
Titante			10		5	5						5	10					5		5	5	5			
Apatite																									

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

The scapolite pockiloblasts 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 porphyroclasts. Their total average modal composition was 25% in the sections in which it was reported. Garnets (andradite) (= 15% modal composition) occur as distinct crystals only in the eodoskarn, in the exoskarn garnet was anastomosing along the grain edges of porphyroclasts. Vesuvianite has similar form of occurrence and development with that of garnet though it is not observed in the endoskarn.

The neocrystallites within the garnet fence 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-quartz 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 porphyroclastic garnets occur as subhedral medium sized hexagonal prisms by the sides of large and older grains. Opaques are closely associated with cordierite crystals.

Calcsilicate and aluminosilicates characterize the hybrid rocks (hornfels – zoisite, vesuvianite lime-garnet and biotite in contact with cordierite was partially altered to staurolite. Sillimanite in contact with staurolite produced cordierite. Bulbous symplectiles developed from intergrowth of quartz with cordierite.

Trace Elements Contents of the Skarn Rocks

Table 2 presents the trace elements contents of the hybrid rocks (skarns and hornfels). Rb has more or less low concentration 10-22ppm except in the dolerite skarns where the value is 10-34, and an exceptionally high value in one sample (205ppm). Sr was lowest in the dolerite skarns (89-114ppm) with a single exception of one (515 ppm) while it was highest in the pyroxenite skarns (202-1837 ppm) and in the gabrro (204-1667ppm). Zr and Ba two other incompatible elements are more or less consistent in the pyroxenite skarns Zr, (10-317ppm), Gabbro (83-428) and dolerite (10-624). Ni, and Cr and Mn (compatibles) have the highest concentrations Ni (313-5849ppm) and Cr, (49-1428ppm) and Mn (10-1,087ppm).

The rare earth elements (REE) La, Nb, and Nd were not detected in several samples. They range between (10-39ppm), Nd has 60ppm in one pyroxenite skarn Y was detected in all analysed samples and ranged between 17-38ppm. Th was found only in two dolerite skarn samples (10, 39ppm).

K/Ba was more or less consitently low (1-22.58ppm) with the exception of one dolerite samples (598.53ppm). K/Rb and Ca/Sr both have wide ranges; (K/Rb(27.28-1007.49ppm) and Ca/Cr (22.91-3521.98ppm).

Equilibrium Reactions

Five equilibrium bands were observed and reported as distinct skarn isograds in the exoskarn and in the endoskarn between the marble and the intrusives.

(i) calcite-wollastonite
(ii) wollastonite-parawollastonite-scapolite
(iii) scapolite-tremolite-grossularite
(iv) grossularite-andradite-titanite-diopside
(v) andradite-titanite-diopside-plagioclase-pyroxene

Between the intrusives and the schist the following hornfels were reported.

(i) biotite-andalusite-sillimanite
(ii) biotite-staurolite-cordierite-pyroxene
(iii) biotite-stilpnomelane-chlotoid.

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

Mineral assemblage	Temp. range °C	Pressure	H_2O_1 CO_2	Source
1. Cal + Qt_3 = Wo + CO_2	600-840		0.1-0.4	Motoyoshi etal 1992
	550-1,400	10-18kb		Hasellon etal 1078
	550-750	3kb		Greenwood 1967
	450-500	1kb-2kb	0.05-2.2	Ziengbein & Johannes 1981
	580-780	2-6kb	0.2-0.8	Jacobs & Kemck 1981
	780-800	1-6kb	0.8,	
2. 3an = Ca = meionite 6Alb + 2Nacl = marialite	760°	6k bar	0.0-05	Schenk, 1984
3. An + 2Cal + Qt_3 = Gr + $2CO_2$	500-650	1-2k bar	0.0 – 0.35	Gordon and Greenwood 1971
An + 2wol = Gross Wol + Cal = An = Gr + CO_2 1 + ed + Cal + Qt_3	600-800	1-04; 1-5.9	0.25-0.55	Hosehek 1974
And			0.1-0.03	Shumulovich 1978
4. Tr + Cal + Qt = Di + CO_2 + H_2O			0.1-05	Schenk 1984

In a prograde equilibrium reactions; the observed phases are formed by the following chemical reactions.

(i) wollastonite: Cal + Qtz = Wol + CO_2-R_1

(ii) scapolite: 3An + Cal = Meionite – R_{2a}

(iii) Garnet: An + 2Cal + Qtz = Gr + $2CO_2$; An + 2 wol = Gross: R3a Wo + Cal + An = Gr + CO_2; Hed + Qtz = And R_{3b}

(iv) Epidote: Cal + 3An + H_2O = Zepi + CO_2 R_{4a} Scap + Water = Epi + CO_2 (Retrograde) R_{4b}

Zoisite: Cal + 3An + Wat = 2Zoi + CO_2 R_5

Temolite: 5Dol + 8Qtz + H_2O = tre + 3Cal + $7CO_2$ R_6

Vescovianite: Scap + H_2O = vesuvianite + CO_2 + O_2 R_{7a}

Scapolite = Vesuvianite + Cal. R_{7b}

Diopside: Tre + Cal + Qtz = Diop R_8

Titanite: 2 Rutile + 3An + Cal + 2Qtz = 2Titanite + Scap. R_9

Andalusite: Musc. + Qtz = K.fspar + and + H_2O R_{11}

Sillimanite: andalusite = Sillimanite R_{12a}

Staurolite + Musc. + Qtz = Sil + gar + biot + H2O R_{12b}

Staurolite: Chlorite + muscovite + garnet = staur + bio + qtz + H_2O. R_{13}

Chloritoid: St + Sil + grt = Chloritoid R_{14}

Cordierite: Bio + Mus + Qtz = K-fpar + Cord. + Ilm + H_2O R_{15}

The reactions R_1-R_{7a} are marble related and occurred either at the exoskarn or endorskarn. In both zones decarbonation took place. In reactions R_{11}-R_{15}, 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 R_1-R_{15} otherwise carbonate minerals will persist. A fluid phase is considered a general driving force for metamorphic reactions. Fig 2 is a composite diagram consisting of two integral parts (a&b). The part a (up) is after Motoyoshi (1992), and Schenk (1984). The 1st part (a) of the diagram is a T – XCO_2 diagram illustrating reaction curve in the system CaO – Al_2O_3 – SiO_2 – CO_2 – H_2O at isobaric Pf = 6kb. CO_2 ranges between 0.00 – 0.5. The 2nd part (b) is the H_2O and CO_2 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 CO_2 and H_2O, rise from very low values at the intrusive end to much higher values towards the marble. The CO_2 values seem complimentary to those of H_2O until at the point where the skarn is most conspicuous. At this point the value of CO_2 rose suddenly above the value of H_2O. 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, Pload = 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 amphibolite grade of the regional metamorphic terrane prior to intrusion of the gabbroic plutons.

(ii) the low permeability of the Ubo marble.

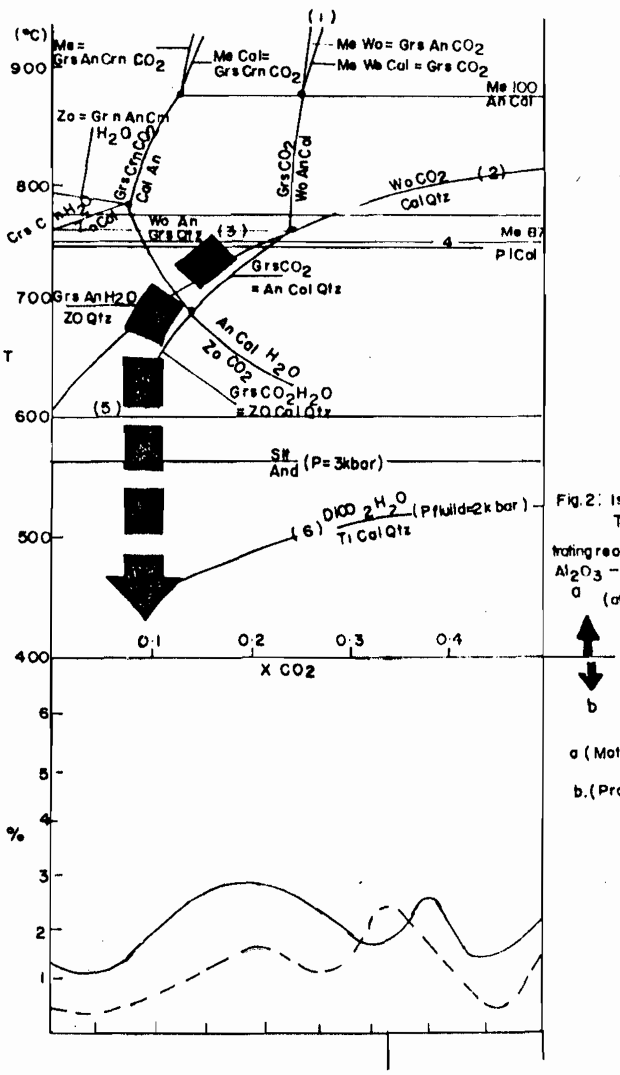

Fig. 2: Isobaric (Pf = 6 T–X_{CO_2} diagram relating reaction in the system Ca Al_2O_3 – SiO_2 – a (after Schenk, 1984.)

a (Motoyoshi : (1991)

b. (Project data).

Fig. 2: Isobaric diagram relating reactions in the system CO_2 – Al_2O_3 – SiO_2 – CaO.

Marbles are considered the least permeable of the country rocks reported (including calc-gneiss, H_2O – CO_2 0.01 – 0.05 gneisses, schists, quartzites and other felsic rocks (Brenan, 1991). However, the H2O-CO2 (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 advectional heat energy from late intrusive bodies. For a comprehensive baric 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 equilibra and the temperatures and pressures ranges at which equilibra are attained. Joesten (1976) reported the occurrence of meionite, rankinite, spurrite, tilleyite 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 mellilite 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 larnite (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 discrmination

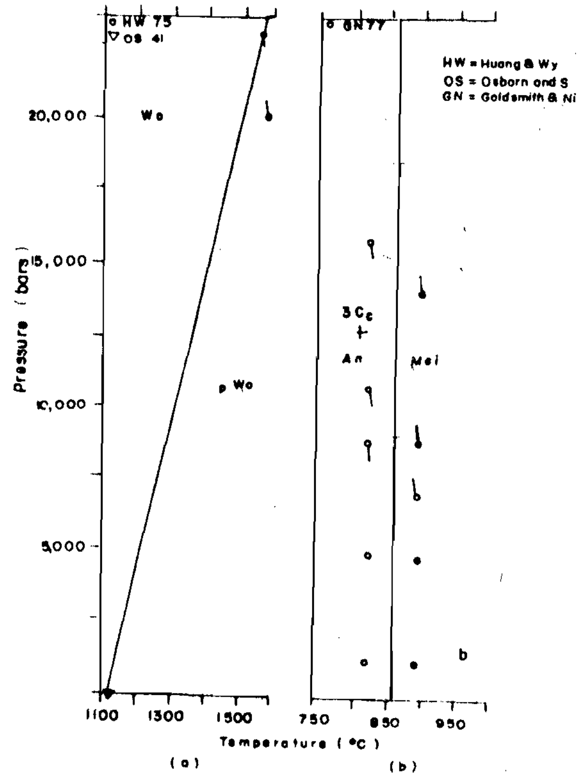

Fig. 3 Contact metamorphic reactions and products at variable Temp & Press after – Berman 1988.

Table 3: Trace Element ratios in the rocks

Table 3		Gabbro Skarn												
	27	28	29	31	34	35	35	36	37	42	43	44	45	46
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
K/Rb	476	409	478	409	27	491	1007		273	191	273	262	737	187
Rb/Sr	0.01	0	0	0.01	0	0	0		0.04	0.01	0.01	0.01	0	0.01
K/Ba	13.8	10	15	9.16	0.9	2.61	12.6	4.06	9.34	13	12.6	22.6	12.5	12.1
Ba/Sr	0.25	0.4	0	0.23	0.3	0.74	0.08	0.09	1.22	0.08	0.16	0.11	0.01	0.31
Ca/Sr	141	240	166	446	766	320	22.9	90.25	764	488	763	526	461	359
Rb/Ba	0.03	0	0	0.02	0	0.01	0.01	-	0.03	0.07	0.05	0.09	0.02	0.04

Table 3 continued trace element ratios in the rocks

Table 3	Dol Skern		Gabbro Skarn	Horn Fels		
	71	74	75	90	127	137
	15	16	17	18	19	20
K/Rb	631	172			211	549
Rb/Sr	0.02	0.02	6.93	0.01	0.02	0
K/Ba	599	-	-	-	14.7	14.7
Ba/Sr	0.25	-	17.4	0.08	0.3	0.09
Ca/Sr	554	352.9	3522	108.91	94.7	150
Rb/Ba	0.95	-	-	-	0.07	0.03

tools useful in distinguishing a skarn assemblage either felsic/mafic intrusive phases or even metamorphic rocks TiO_2/Al_2O_3 A.I/Al_2O_3,Ni/Mg, K_2O/S_1 S_2, Ba/Rb, Ba/Zr Th/U, Th/Pb. Zr/Nb, Y/Nb all show linear relations in the skarns but not so with the mafic and felsic intrusives,K/Rb, Sr/Y have similar trends in both skarn types and the intrusives 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.

Auwera and Andre (1991) reported a similar trend in which the different types of skarns were enriched in the REEs. The authors suggested fhrter that, the REE patterns suggest tht 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.

Brickle and Kenzie (1987) slightly differ in their report that the time scale for advective or diffusive transport of any atomic spĕcies is inversely proportional to the partition coefficient of species between solid and fluid. While that assumption may be correct to quite 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 anatexis where a fluid phase could be distinct from a crystallized separate phase. One may on the strength of available evidence from this work question the sources of Pr and Ho to suggest a non-magmatic, non-hydrothermal fluid probably buffered that which infiltrated the skarn bodies. While on their individual bases the trace elements and REEs were reported by Lummen and Verkaren (1986), the heavy rare earths (HREE) and SiO_2, Al_2O_3, FeO, TiO_2 and most of the trace elements were reported to remain constant, Na_2O, Rb,Sr, Ba and the light rare earth (LREEs) contents are reduced. This is true for most individual elements, but the distribution ratios of certain elements become distinctively characteristic. At level best, 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 became 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 – dipside; diopside – titante – plagioclase isograds in the Ubo area.

A few minerals are formed in the course of retrograde processes with characteristic symplectitic 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 baric conditions, were involved in the metamorphic processes. A pervasive fluid flow could have not been probable considering the thinness of the skarn widths which were limited by the low permeability of the country rock that inhibited any fluxing of fluid with no possibility of being channelized

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