The Origin of Formation of the Amphibolite-Granulite Transition Facies

by

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ABSTRACT

The origin of formation of the amphibolite-granulite transition facies may be from deep burial in the earth's crust or it may come from the tectonic process of an orogenic event related to continental collision zones.

Temperatures needed to form this transition facies are on the order of 650°C to 800°C, with the accompanying pressures of 5 to almost 8 kbar. These conditions of temperature and pressure can be met by each above hypothesis for the transition facies. In the deep crustal model, it is known that upon reaching the depths of 10-35 km the temperatures and pressures at this depth are suitable to form this facies. Similarly, in the hypothesis of the orogenic event, these temperature and pressure conditions can be created by a descending slab of continental material into the earth's interior.

In order to come to a conclusive opinion on which hypotheses formed the transition facies, a study of the facies involved must be completed.

This includes: defining the facies involved by their mineral compositions, evaluating the temperature and pressure conditions which affect the formation of the facies involved, and taking into account the content and composition of H_2O and CO_2 activities in fluid inclusions found in these facies.

Finally, a description and study of the two previous mentioned hypotheses has been carried out and a conclusion as to which process formed the amphibolite-granulite transition facies is stated.

QUESTION OF THE TRANSITION FACIES ORIGIN

The amphibolite-granulite transition facies is defined as a set of minerals in which all of these minerals have formed under similar conditions of metamorphism. These conditions are temperature and pressure. Presently there is debate as to the origin of this transition facies. The two main groups of thought are as follows:

1. The transition facies represents ancient deep crustal material. The temperature and pressure conditions present in the deep crust would be capable of producing the minerals found in this facies.
2. The transition facies represents the product of tectonic activities (processes of large scale

deformation), such as continental collision zones.

The two above hypotheses represent the two most credible explanations for the origin of formation of the transition facies. After defining the facies involved (amphibolite, granulite, and their transition facies), describing the temperature and pressure conditions under which these facies formed, taking into account the activities of CO_2 and H_2O in fluid inclusions, an evaluation as to the origin of formation of the transition facies can be made. The two previous mentioned hypotheses are described and evaluated as to the likelihood of producing the transition facies. The most probable environment of formation of the amphibolite-granulite transition facies can then be named and stated in the conclusion.

DEFINING THE FACIES INVOLVED

Amphibolite Facies

The amphibolite facies is a mineral assemblage that develops in rocks of medium to high grade metamorphism. The most characteristic mineral pair of the assemblage is hornblende and plagioclase (Miyashiro, 1973). There are four typical mineral groupings, based on overall mineral composition, of which the minerals involved can be classified under. These are pelitic, basic, calcareous and magnesian. They are as follows:

Pelitic: quartz-muscovite-biotite-almandine; with or without staurolite and kyanite. Andalusite occurs in lower pressure series, while sillimanite is present at maximum grades of metamorphism.

Basic: hornblende-plagioclase; with possible additional phases of epidote, almandine, or diopside.

Calcarious: calcite-diopside-tremolite; also calcite-grossularite-zoisite (clinozoisite).

Magnesian: Tremolite-forsterite; with antigorite, talc, anthophyllite or enstatite as an additional phase.

This amphibolite facies is widely distributed in the Proterozoic and Phanerozoic metamorphic belts for regional metamorphism (Turner, 1981), see Fig. 1. These amphibolites are derived mainly from igneous rocks; however, some may also come from impure calcareous sediments (Miyashiro, 1973). It has also been found that these amphibolites can display schistositic or compositional banding textures.

Examples of the amphibolite facies can be found in the Orijarvi area, Finland; in the Dalradian area, Scotland; and in the New Hampshire-Vermont vicinity, United States.

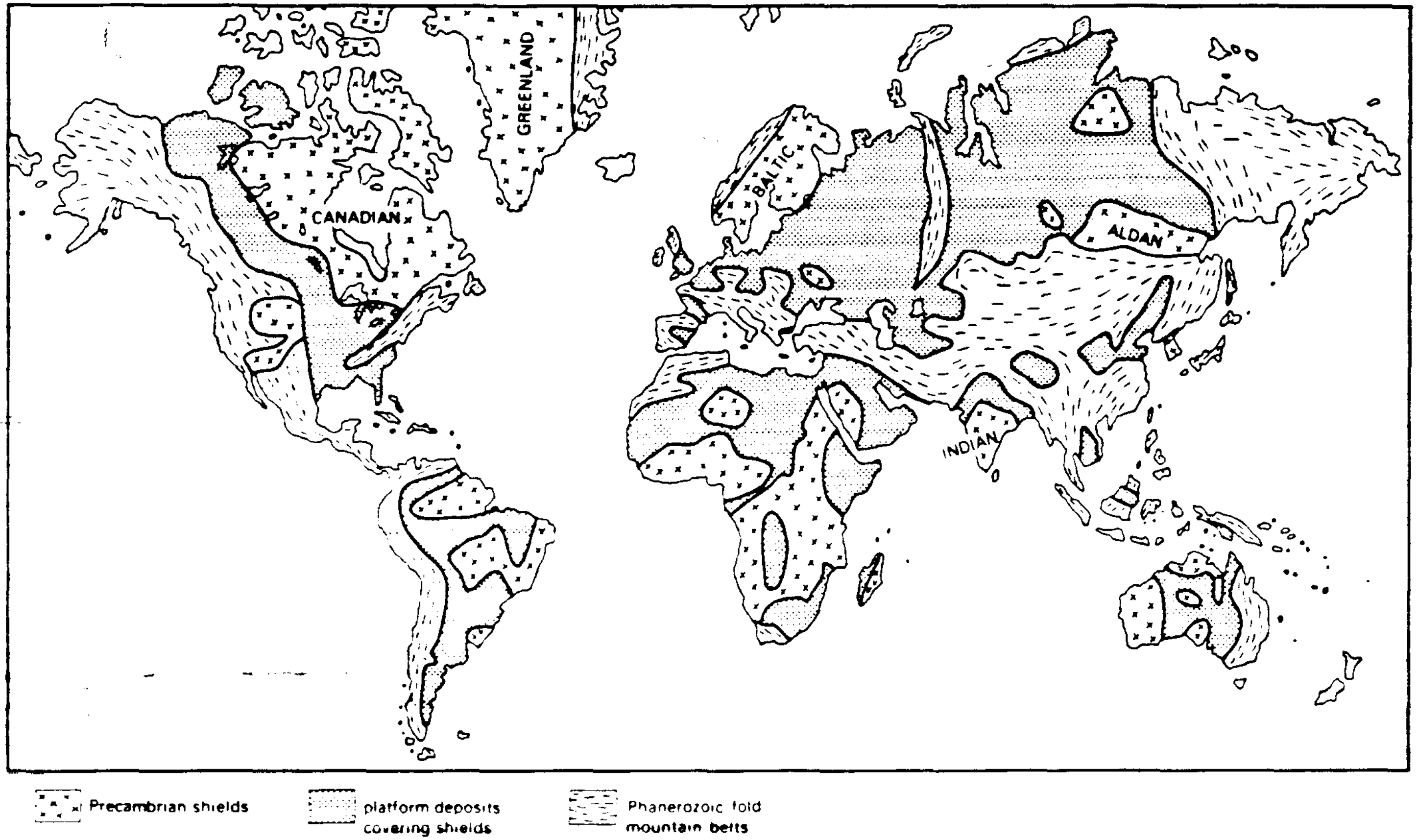

Fig.1 **Precambrian shields, platform sediments and Phanerozoic fold mountain belts.**
(Gillen,1982)

Granulite Facies

The granulite facies is a mineral assemblage that develops in rocks of higher metamorphic grade than that of the amphibolite facies. The minerals in the granulite facies are associated with extreme dehydration at maximum grades of regional metamorphism (Turner, 1981). Typically, the differences from the amphibolite facies are largely the absence of white micas; biotite (usually phlogopitic); and hornblende may all be absent. These minerals, absent in the granulite facies, are commonly prevalent in the amphibolite facies. As with the amphibolite facies, the granulite facies can be defined by four major mineralogic groupings, based on the overall mineral composition. These are the pelitic, basic, calcareous, and magnesian. They are as follows:

Pelitic: quartz-perthite-sillimanite-almandine; with additional phases of cordierite, biotite and kyanite.

Basic: plagioclase-diopside-hypersthene (-garnet).

Calcareous: calcite-diopside-forsterite (-scapolite, corundum).

Magnesian: Forsterite-enstatite-spinel (Turner, 1981).

These granulite facies are widespread in Proterozoic belts and Precambrian shield areas (see

Fig. 1). Associations with anothosite massifs are also present in some Precambrian belts (Miyashiro, 1973). Many of these granulite terrains are bounded by transitional zones of progressive metamorphism (Newton, 1985). It has also been found, that the garnets present in this facies are largely almandine carrying 20-25 percent pyrope and 15-20 percent grossularite.

Examples of the granulite facies can be found in the Adirondack massif, New York state; in the Central Highlands, Ceylon; and in the Grenville belt of Quebec, Canada.

Amphibolite-Granulite Transition Facies

Unfortunately, few amphibolite-granulite transition facies have been studied in great detail However, the transitional terrains of southern Karnataka, South India (Janardhan, et al., 1982); southwest Australia (Wilson, 1978); and southwest Greenland (Wells, 1979) have been studied and give some insight to the transition facies. It is debatable how these transition zones form, but the above areas mentioned are interpreted as being rested prograde granulite formation (Newton, 1985).

Eskola (1939) gives an ideal definition of the granulite transition facies based on ideal associations of phases that may form due to dehydration of micas and amphibolites at the culmination of metamorphism in Precambrian craton. For this transition facies is ideally an intermittent phase between the low grade (both lower temperatures and pressures) of the amphibolite facies to the higher grade (both higher temperatures and pressures) granulite facies in a prograde regional metamorphic system. This means that, the metamorphism of minerals of a particular facies come about due to a gradual increases in both temperature and pressure; an increase in grain size and an increase in mineral density support this (Ehlers and Blatt, 1982).

Turner (1981) lays out the typical mineral characteristics found in the transition facies in the following description. Principal anhydrous end members are combinations of feldspars, sillimanite (or kyanite), almandine rich garnets, cordierite and clino-and orthopyroxenes. Muscovite-quartz breaks down into potassium feldspar plus sillimanite. Upon the appearance of biotite to the dehydration reaction, this reaction is lead by a process of continual transformation to the association of cordierite or almandine as well as sillimanite and potassium feldspar. In an additional line of continual reactions, hornblende is eliminated in favor of the diopside-hypersthene pair.

As can be seen, the full amphibolite to granulite transition facies can cover a wide range of temperature and pressure conditions. Additionally, variables such as H_2O, CO_2 and other volitales' compositions come into play. For by these volitales' compositions one can speculate as to how much these volitales affect the production of the characteristic minerals and the environment at which the transition facies was formed. These topics will be addressed in more detail further in the discussion.

CONDITIONS OF FORMATION FOR THE FACIES INVOLVED

For each metamorphic facies there is a range of temperature and pressure conditions on which the minerals in the particular facies are formed, and these conditions define the facies in question. In order to understand the facies involved, a description of each facies pressure and temperature conditions will be given.

Amphibolite Facies

The amphibolite facies has already been defined earlier based on the minerals that make up the facies. In the following discussion the pressure and temperature conditions of the facies as well as which minerals in the facies indicate pressure and temperature conditions will be given. General placement among metamorphic mineral assemblage as well as pressure and temperature ranges for the amphibolite facies are shown in Figs. 2 through 4.

A variety of amphibolite subfacies exist depending on rock composition and metamorphic conditions (see Table 1). Polymorphs of Al_2SiO_5 (almandine and staurolite) appear; kyanite versus andalusite which may be supplemented by roles of almandine and cordierite in pelitic assemblages. These serve as a basis for distinguishing between the low and high pressure series (Turner, 1981). The two main divisions of the amphibolite facies relating to the conditions of metamorphism are low to high pressure series. They are outlined as follows:

High Pressure Series: Kyanite is the first Al_2SiO_5 polymorph for this series in the pelitic assemblage. It gives way to sillimanite with

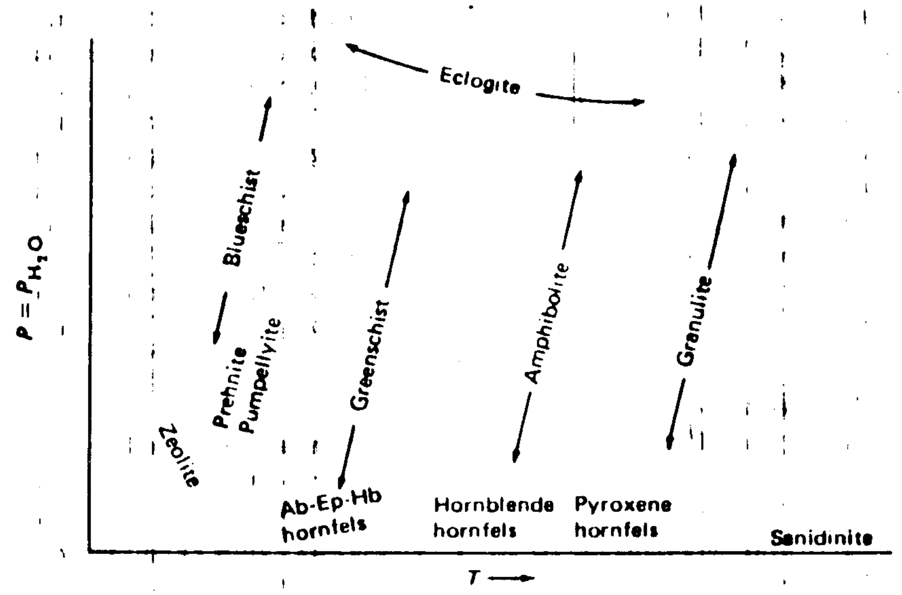

Fig.2 Metamorphic facies placement(Turner,1981)

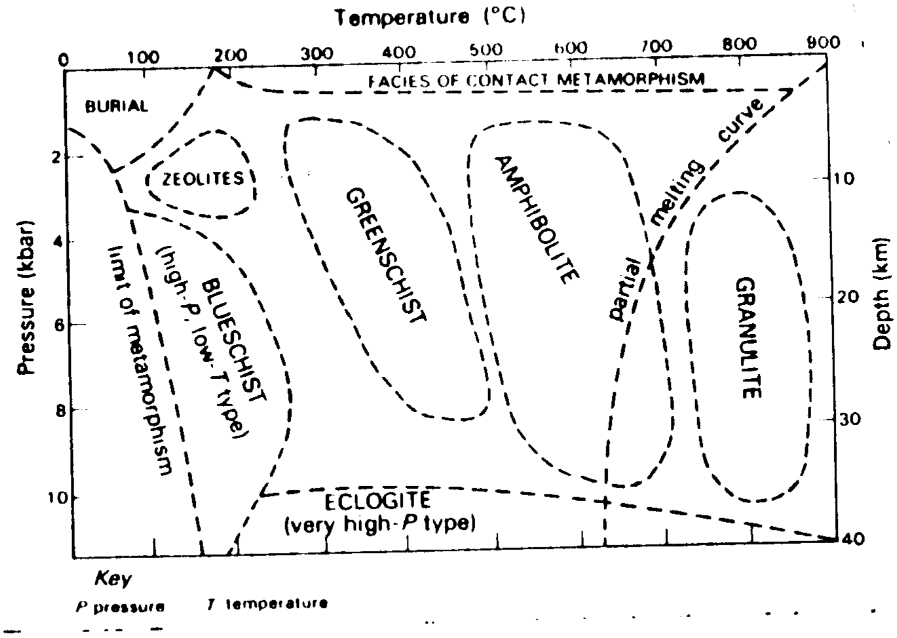

Fig.3 Temperature and pressure conditions for metamorphic facies(Gillen,1982)

Temperature, °C	*Low pressure* [Lithostatic pressure generally less than 3,000 atm (depth < 10 km). Water pressure variable. Conditions typical of contact metamorphic zones]	*Moderate to high pressure* [Lithostatic pressure and water pressure approximately equal, generally 3,000–12,000 atm (depth 10-40 km). Conditions typical of regional metamorphism]
250–550	*Albite-epidote hornfels facies* Sh: quartz-albite-muscovite-biotite Ma: albite-epidote-actinolite-chlorite	*Greenschist facies* Sh: quartz-albite-chlorite-muscovite and quartz-albite-muscovite-biotite Ma: albite-epidote-actinolite-chlorite
400–650	*Hornblende hornfels facies* Sh: quartz-plagioclase-microcline-biotite-muscovite Ma: plagioclase-hornblende	*Amphibolite facies* Sh: quartz-plagioclase-muscovite-biotite-almandine Ma: plagioclase-hornblende
Over 500	*Pyroxene hornfels facies* Sh: quartz-plagioclase-orthoclase-cordierite-andalusite Ma: plagioclase-diopside-hypersthene	*Granulite facies* Sh: quartz-plagioclase-orthoclase-garnet-sillimanite Ma: plagioclase-garnet-hypersthene-quartz
Over 600	*Sanidinite facies* Sh: tridymite-cordierite-mullite-glass Ma: plagioclase-diopside-hypersthene	*Eclogite facies* Sh: Not found Ma: omphacite-garnet

Table 1 Metamorphic facies(Krauskopf,1979)

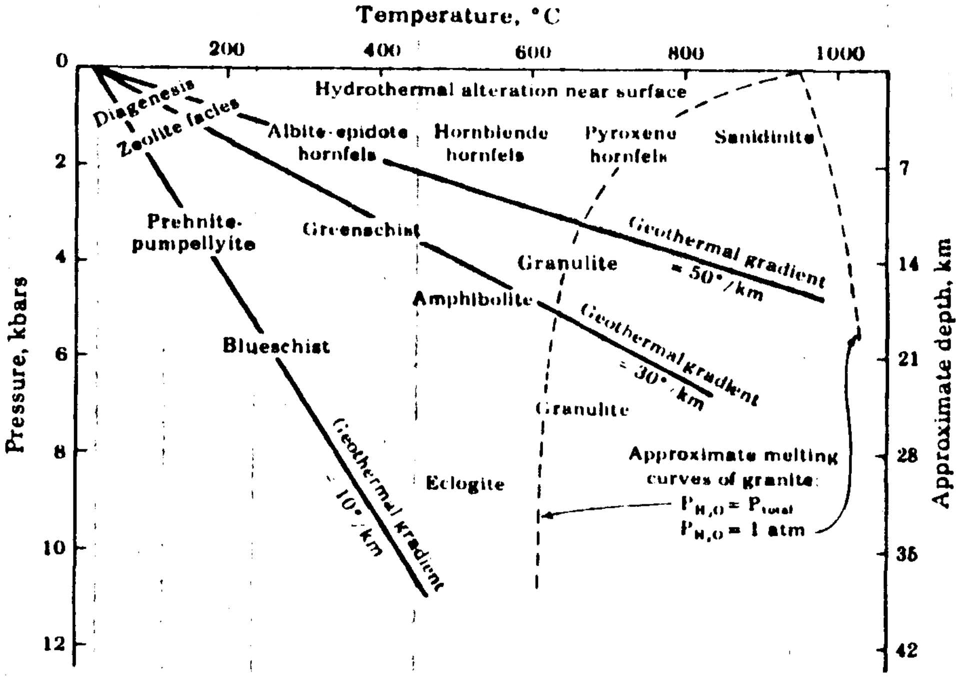

Fig.4 Temperature and pressure conditions for metamorphic facies(Krauskopf,1979)

increasing grade. Where plagioclase is found (An_{25} - An_{50}), almandine and/or epidote are common (Turner, 1981).

Medium Pressure Series: This series corresponds roughly to the kyanite and sillimanite zones. Plagioclase (andesine or labradorite) and hornblende compose the metabasite facies. Hornblende having a green or brown color. Almandine may be present, but epidote is absent (Miyashiro, 1973).

Low Pressure Series: In the pelitic zone; andalusite and/or cordierite are present, with a grossularite and wollastonite in the calcareous rocks. Almandine is absent and epidote is rare. Typically, this series is found near intrusions of granitic plutons (Turner, 1981).

In summary of the pressure conditions, the best pressure indicators are the Al_2SiO_5 polymorphs.

In relation to the temperature conditions present, Miyashiro (1973) noted that one of the best indicators is that of the mineral hornblende's color. As temperature increases the color of hornblende goes from a blue-green through green to brownish green and brown. Also, another indicator of high temperatures are the presence of cummingtinite and clinopyroxene; with plagioclase being oliogoclase, andisine or labradorite. For the lower temperature series, andalusite represents the Al_2SiO_5 polymorph with sillimanite as the high temperature Al_2SiO_5 polymorph. Muscovite is stable in the lower temperature series, staurolite disappears. In addition Suk (1983) noted, the conversion of actinolite into hornblende represents the boundary between the low and medium grades of metamorphism. Also, the increase in metamorphic grade is represented by a rise in alkalies (Ti, Fe, Al in tetrahedral coordination, and a decrease in Si and Mg contents). He also gave the range of amphibolite facies with 600-650°C temperatures and pressures on the order of 220 MPa.

Granulite Facies

The granulite facies represents yet a higher grade of metamorphosed minerals than those of the amphibolite facies (see Figs. 2-4). Miyashiro (1973) defined the facies as representing regional metamorphism. Metapelites of low pressure regional metamorphism exist, with cordierite and also almandine. Since pyrope content of almandine is less than 30 percent, this indicates that pressures were at, or lower than medium pressure granulite facies.

The medium pressure granulite facies is characterized by metabasites, which clinopyroxine and orthopyroxine formed by the decomposition of hornblende. These decomposition reactions are very gradual, creating a wide zone of hornblende, biotite, orthopyroxene and clinopyroxene existing together (Miyashiro, 1973). In metabasites of medium pressure granulite facies, plagioclase is common but decreases in amount in garnetiferous varieties. This is due to the fact that garnet forms partly at the expense of plagioclase (Miyashiro, 1973). Almandine-pyrope exists and sometimes is abundant in metapelites and metabasites of medium pressure. These metapelites are composed mainly of quartz, plagioclase, K-feldspar, garnet and sillimanite with biotite. Orthoclase or sanidine is the stable form of K-feldspar, but microcline is common due to a retrogressive change (Miyashiro, 1973).

In the low pressure granulite facies, cordierite is common with the Fe^{+2}/Mg ratio of almandine being high. In the medium pressure facies, cordierite is absent and the Fe^{+2}/Mg ratio of almandine is usually lower. Pyrope content of almandine can be up to 55 percent. Cordierite absence is due to its instability at higher pressures.

Amphibolite-Granulite Transition Facies

In the amphibolite-granulite transition facies, the minerals present represent a gradation of minerals of the amphibolite facies to minerals of the granulite facies under increasing temperature and pressure. The best way to explain these conditions for forming the transition is to show a well document case of the Northwest Adirondacks of New York. Original work/study was done by Buddington (1963), Buddington et al., (1963), Engel and Engel (1960, 1962a, 1962b) and DeWaard (1964, 1965a).

The following description of the granulite-amphibolite transition facies at the Adirondacks is that of Buddington (1939).

In the northern New York state, the Adirondack massif and the adjacent Grenville lowlands to the west are extensions of the Grenville tectonic province. All components of the massif (plutonic, volcanic and sedimentary) are affected by the high grade regional metamorphism of the Grenville tectonic province of the late Proterozoic.

A summary of the prograde metamorphism is as follows:

1. Systematic and characteristic changes in the metamorphic

assemblage of minerals in the paragenesis, amphibolite and associated marble.

2. An increase amount of igneous looking granite and an increase in the ratio of igneous to metasomatic granite.
3. Appreciable increases in the grain size of minerals.
4. An increase in dehydration, reduction and basification of the paragenesis and amphibolite. Also, a progressive decarbonation of the marble.
5. A decrease in thickness of paragenesis and marble.
6. A zonation in the distribution of mineral deposits formed during specific stages of the regional metamorphism.
7. Systematic changes in solid solution ratios of O^{18}/O^{16} in oxides and silicates, and in other temperature dependant mineral proportions.

Estimated depth of overburden of metamorphism is at least 10-20 km. Gneiss and marble thickness (2-3 km) suggest a metamorphic model in which the load pressure is 3-5 kbar.

Progressive changes in mineral paragenesis from a.) the amphibolite facies near Emeryville to Edwards to b.) the granulite facies at Colton are as follows.

In amphibolite (figures are mean modal percent):

a.) Hornblende (68)-andesine (19)-quartz (10)-ilmenite (2)-diopside (0.5)-ephine (0.5)

b.) Hornblende (22)-labradorite (39)-diopside (21)-hypersthene (14)-ilmenite (3.5).

In the metasedimentary semipelitic gneiss:

a.) Quartz-biotite-oligoclase (minor muscovite, microcline, magnetite).

b.) Quartz-oligoclase (calcic)-almandine (minor K-feldspar).

In marble:

a.) and b.)
1. Calcite-quartz
2. Calcite-phagioclase (andesine to anorthite)-phlogopite
3. Calcite-quartz-diopside (some undestroyed dolomite).

On the basis of mineral changes you can draw three isograds. In order of increasing grade they are:

1. Disappearance of sphene in amphibolites.

2. Appearance of abundant diopside in amphibolites.

3. Appearance of hypersthene giving the granulite assemblage plagioclase-hornblende-diopside-hypersthene.

To further describe the conditions of the amphibolite-granulite transition zone the transition facies of the Broken Hill district in South Central Australia will be laid out. This comes from the work of Binns (1964, 1965).

This area represents high grade mid-Proterozoic metamorphic rocks. This is an area of repeated metamorphism. Dominant rocks are amphibolites of basaltic composition and quartzofeldspathic granitic gneisses called metasediments. Pelitic rocks are few and calcareous rocks are rare. There are three metamorphic zones defined. They are:

Zone A: Paragenesis of the amphibolite facies.

1. Basic: hornblende-plagioclase (-labradorite-bytownite)-quartz-ilmenite.
2. Pelitic: sillimanite-muscovite-mitotite-quartz-ilmenite.
3. Quartzo-feldspathic (granite): quartz-plagioclase-K-feldspar-biotite.
4. Minor calcsilicate combinations of phagioclase, tremolite, diopside, hornblende, epidote minerals, vesuvianite and wollastonite.

Zone B: Paragenesis represent maximum grade in amphibolite facies.

1. Amphibolites are characteristic of Zone A, however, hornblende is more brown or greenish brown instead of greenblue.
2. Muscovite is absent from pelitic rocks.
3. Almandine becomes dominant in the quartzo-feldspathic assemblage.

Zone C: Paragenesis now is that of the granulite facies.

1. Basic: hornblende-pyroxenes-plagioclase. Pyroxenes being diopside and hypersthene. Hornblende decreases in quantity.
2. Muscovite absent from pelitic, now represented by sillimanite-biotite-almandine-cordierite-biotite, almandine-cordierite-biotite-orthoclase-quartz.

The chemical reaction of the transition from paragenesis of Zone A to Zone B would be:

$$Ca_2(Mg_4Al)(AlSi_7O_{22})(OH)_2 \rightarrow CaAl_2Si_2O_8 + CaMgSi_2O_6 + \underset{\text{enstatite}}{3MgSiO_3} + H_2O$$

Temperature indicators such as the magnetite-ilmenite give temperatures for Zone C of 600-670°C. In the Adirondacks it was on the order of 550-625°C for the same granulite facies minerals.

ACTIVITIES OF CO_2 AND H_2O

The role of the fluid inclusions of H_2O and CO_2 give insight to the environment in which the transition facies was formed. It is known that most metamorphic reactions involve the participation of one or more components of the pore fluids. The pore fluid, except in the case of water in the surface hydrothermal system (T $<374_0$C and depth <750m), is a gas (Turner, 1981). The course of metamorphic reactions and the P-T fields of stability of the resulting mineral assemblage are very much influenced by the composition of the pore fluid and its response to changes in fluid pressure (P_f).

There has been a strong emphasis on the role of CO_2 pressure in decarbonation reactions. In Touret's (1971) discovery, he reported that microscopic fluid inclusions rich in CO_2 were found in some Norwegian granulites. This suggests that the corresponding low fH_2O, rather than very high temperatures, may have been responsible for forming the granulite facies. Fluid inclusions in the adjacent amphibolites are rich in fH_2O (Turner, 1981).

The dehydration of amphibolite facies is known to produce granulite facies of prograde metamorphism found in southern Norway (Turner, 1981). The CO_2 is believed to be the main component of the fluid phase in the deeper crust (Suk, 1983). Further support of CO_2 fluid inclusions as the dominant species, and H_2O secondary for fluid inclusions in granulites, is stated in Newton (1985).

The preceding discussion of the minerals involved in the amphibolite-granulite transition facies show that the temperature for most granulite metamorphism is near 700-900°C, with pressures of 5-10 kbar. The transition phase being lower, with temperatures of 600-800°C and pressures of 5-8 kbar. With the amphibolite facies even lower (Newton, 1985).

HYPOTHESES OF FORMATION

The process which can create such pressures and temperatures needed for this metamorphism is burial in the deep crust or a tectonic event known as orogeny at a continent collision zone.

Deep Crust Model

The deep crust can produce the pressures and temperatures needed for the formation of the amphibolite-granulite transition facies, if the depth is on the order of 10-35 km (see Fig. 5). The evidence for this model includes the high density minerals found in the facies, which seem suitable to conditions of the deep crust. Also the depletion of large ion lithophiles (LIL) in the

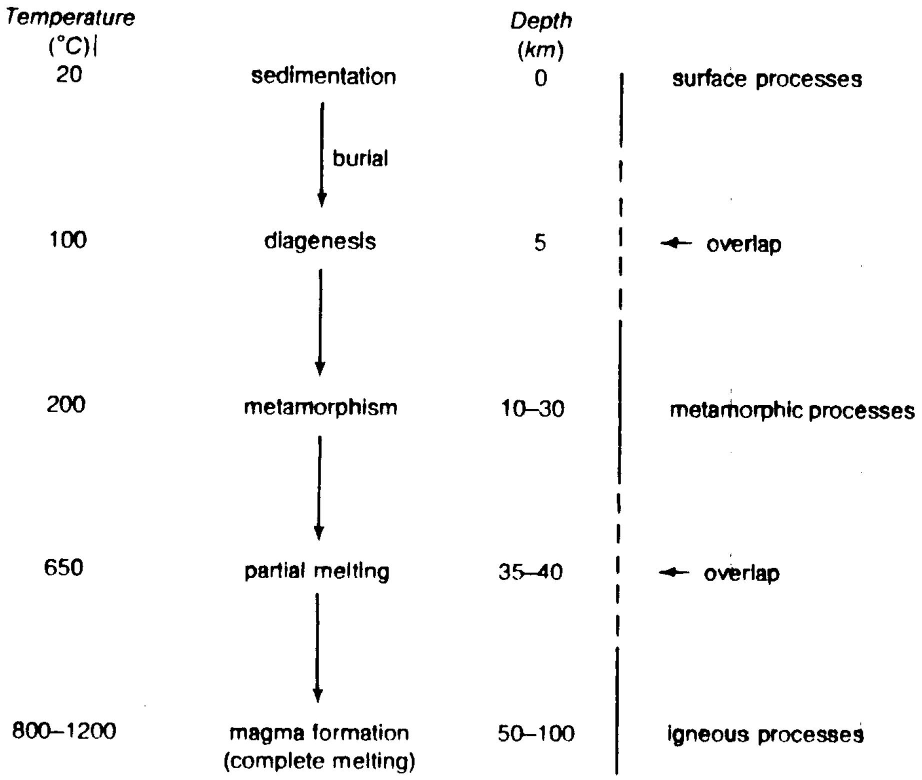

Fig.5 Transformation processes with depth(Gillen,1982)

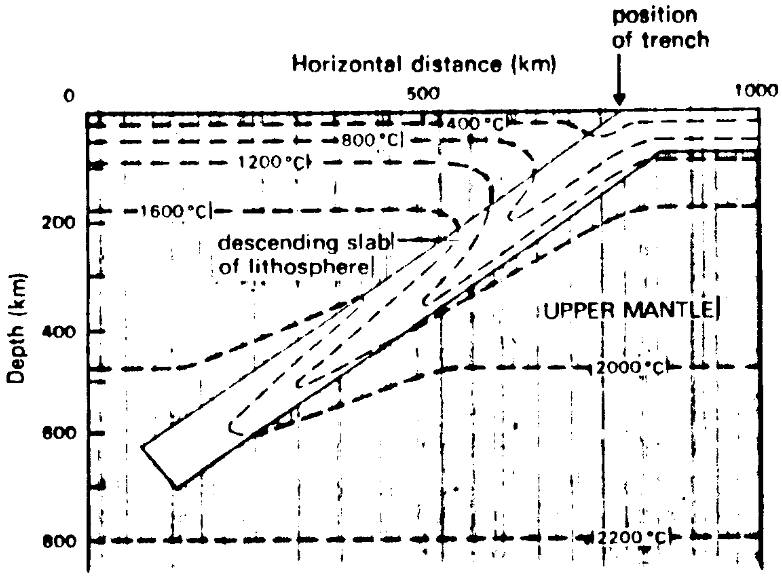

Fig.6 Temperature versus depth of a descending continental plate(Gillen,1982)

facies represents a heat-flow-modelling found in the deep crust (Newton, 1985). As mentioned before, CO_2 fluid inclusions pay a major role in the formation of the facies. This CO_2 is believed to be the main fluid phase found in the deeper crust (Suk, 1983). The LIL include Rb and K. This source of CO_2 could be an outgasing mantle, deeply buried carbonate rocks, or exsolution from basaltic intrusions (Newton, 1985).

Orogeny Model

Another possible explanation for the formation of the amphibolite-granulite transition facies is that of an orogenic event. An orogenic event is any natural process which causes a large scale change of a land mass over an indefinite time period (Selby, 1985). But in order to understand this process, one must first understand the internal composition of the earth.

The Earth

The earth's surface is composed of mostly silicate material called the crust (see Fig. 7). Its thickness varies from 10 to 65 kilometers.

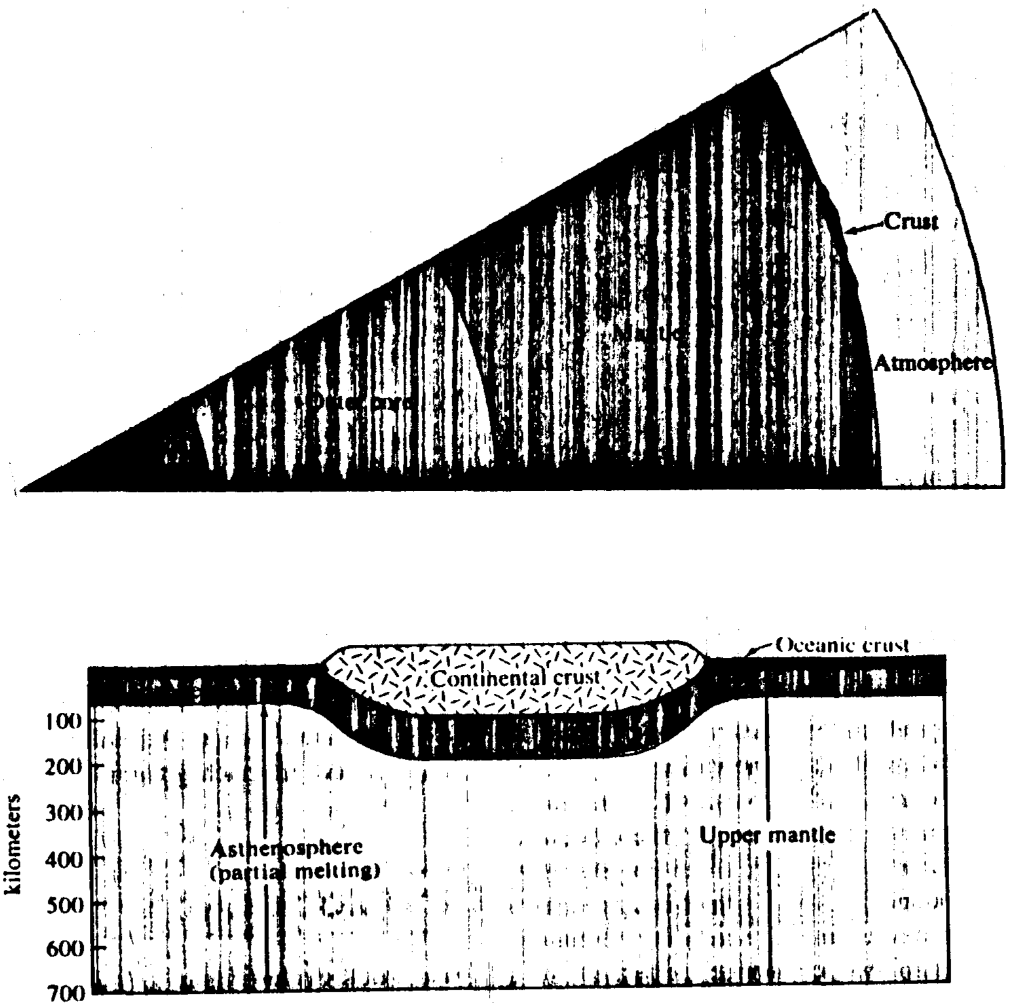

Fig.7 Cross-section of the earth(Lutgens et al.,1982)

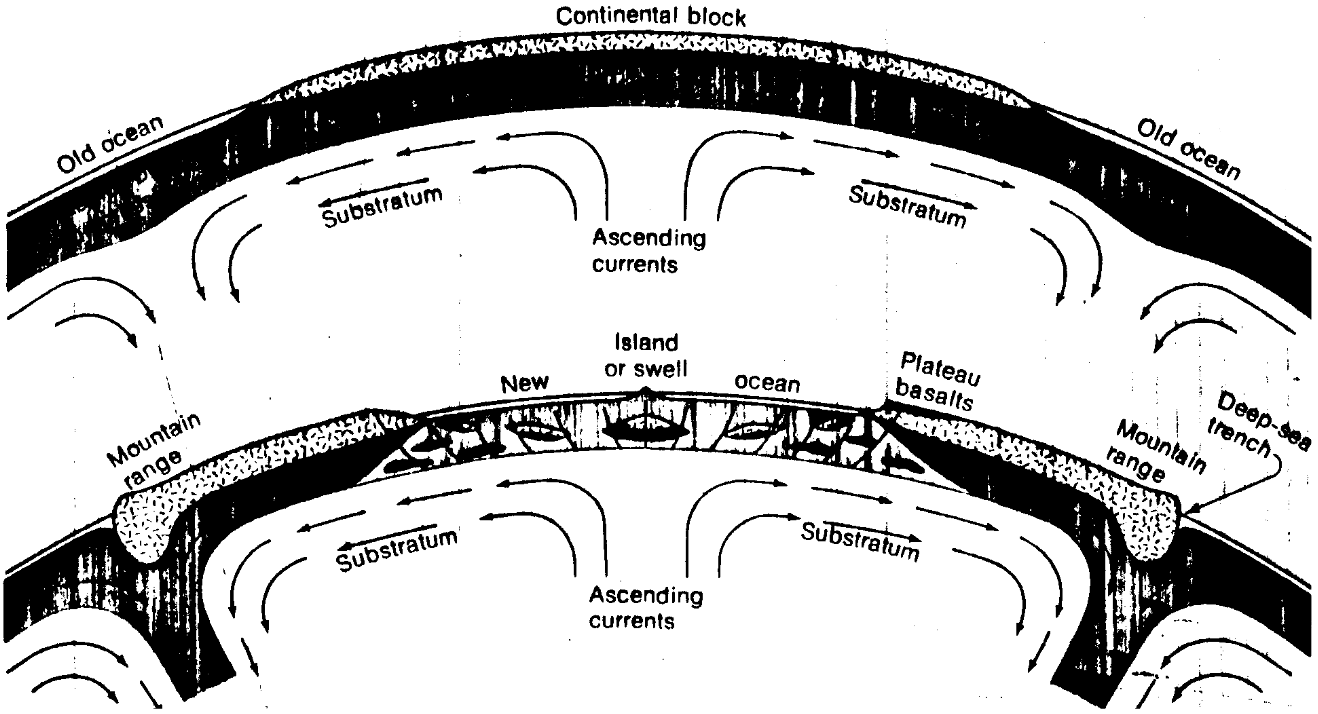

Fig.8 Cross-section of the earth(Press and Siever,1974)

Underlying the crust is the mantle; it is composed of mostly silicate material rick in iron, magnesium, aluminum and calcium. The mantle is divided into three layers. These layers are, in increasing depth: the lithosphere, the asthenosphere, and the mesosphere (Larsen and Birkeland, 1982). The center and innermost portion of the earth is called the core. The core is mostly molten, very dense, and composed mostly of iron. It is also known, that as depth increases in the earth's interior, the corresponding pressures and temperatures also increase (see Fig. 6).

Plate Tectonics

The orogenic events mentioned earlier stem from the earth's internal composition and theory known as plate tectonics. This theory states that the earth's crust and part of the underlying lithosphere are divided into seven large plates. These plates, due to the internal energy of the earth, move. Along the plates' margins, where the plates meet, deformation and changes of the land masses take place. Smaller scale, specific events of a given area along these plate margins are classified as orogenic events (Davis, 1983).

Orogenic Events

These orogenic events can be classified into three groupings:

1. Zones of Convergence
2. Zones of Divergence
3. Zones of Lateral Motion

For our purposes, only the process of converging zones needs to be studied. A converging zone is an area in which the motion of two or more plates causes the plates to converge or collide with each other. It follows from this, that one of the plates is pushed down relative to the other plate (see Fig. 6). This descending plate travels into the earth's interior (Larson and Birkeland, 1982). In addition, the converging zone can be divided into two categories:

1. Continent-Continent Collision
2. Continent-Ocean Collision

Continent-Continent Collision

In the case of continent-continent collision, two or more continental plates (dry land masses) come together due to the internal energy of the earth in the form of convection currents (see Figs. 8-10). These convection currents can arise when

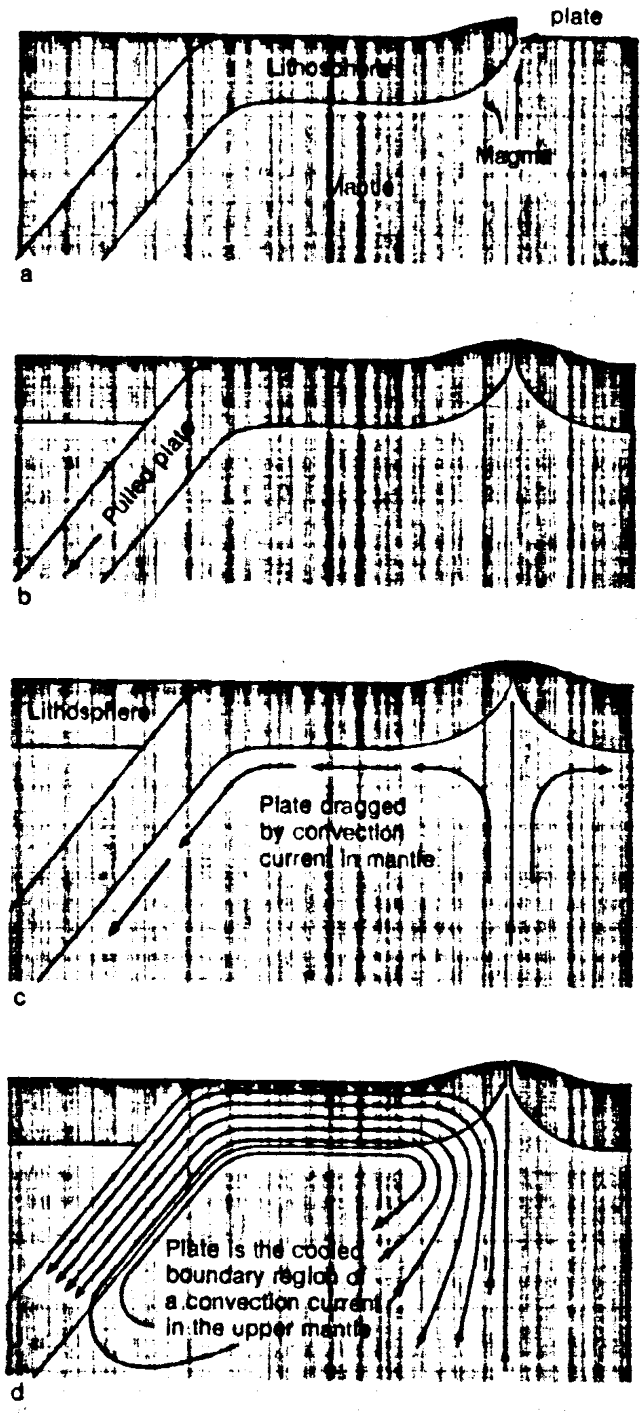

Fig.10 Convection currents(Press and Siever,1974)

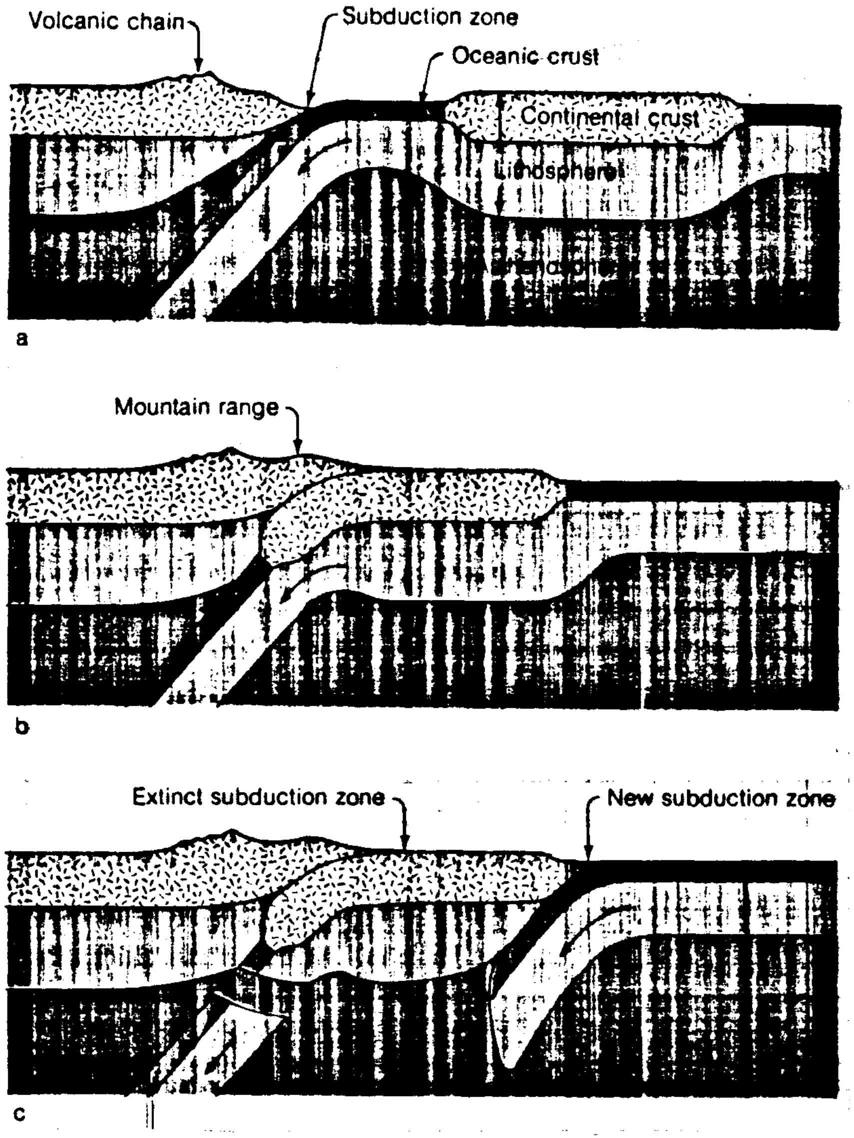

Fig.9 Collision zones(Press and Siever,1974)

heat is generated at a specific location in the earth's interior. As this hotter material rises, it cools and flows laterally beneath the crust. This lateral motion then carries the overlying plates with it (Dott and Batten, 1981). This motion causes the plates to collide. In this case, the continent-continent collision involves an earlier event of oceanic plate consumption since continental plates are usually separated by oceanic plates.

As mentioned earlier, one of the colliding plates must be consumed and descend below the other plate into the earth's interior. The overriding plate margin thus deforms and creates surface features such as mountains and highlands. As the descending plate travels farther into the earth's interior, it is subjected to increasing pressures and temperatures inherent in the earth's interior. This can be seen in Fig. 9. These increasing pressures and temperatures transform the existing rocks and minerals into different minerals, stable at these new environmental conditions. This transforming process is known as metamorphism.

Continent-Ocean Collision

In the case of continent-ocean collision, the description above hold true also. However, due to the basaltic nature (very dense in comparison to continental silicate material) of the oceanic plates, the oceanic plates are the plates usually overridden or subdirected into the earth's interior upon collision.

The two processes described in this discussion, that of continent-continent collision and continent-ocean collision, are two of the many processes which can form the amphibolite-granulite transition facies. The pressure and temperature conditions created by these processes are sufficient to form the mineral assemblage in question, and these processes represent two of the more credible explanations for this mineral assemblage's formation.

CONCLUSION

In summary of the problem of finding the origin of formation of the amphibolite-granulite transition facies, it is believed that these transition facies formed as the result of tectonic process of an orogenic event related to continental collision zones.

The temperatures and pressures needed for the transition facies, 650-800°C and 5-8 kbar respectively, can be created in an orogenic continental collision zone where a descending slab of material travels into the earth's interior. Even though these conditions can be met by the deep crust burial model, the addition facts that as newton (1985) noted, that the most well documented granulite terrains (and associated transition zones) display some type of orogenic features. These features included metasediments (marbles, quartzites, and K-pelites noted by Shackleton, 1976)). In addition, evaporites have been found in many granulite terrains suggesting a continental surface origin. Miyashiro (1973) also supports this above data, by noting that many amphibolite-granulite transition areas are commonly bounded by fault contacts, suggesting a tectonic event taking place to create such a feature.

Therefore, with the above data, it is believed that the amphibolite-granulite transition facies origin of formation is one of an orogenic event involving continental collision.

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