ULTRABASIC TECTONITES AND LAYERED PERIDOTITES OF THE HATAY AREA (TURKEY)

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SUMMARY. — In the light of our recent investigations we can distinguish two types of ultramafic rocks in the Hatay region: ultrabasic tectonites and ultrabasic cumulates. The purpose of this paper is to outline the Origin and the features of these rocks. Basic and ultrabasic complexes are classified according to their geological setting, mode of formation, mineralogical composition, structural and textural features, etc.

The Hatay ultramafics belong to the Alpine type of ultrabasic complexes. The tectonites are characterized by the existence of foliation and lineation. The cumulates show magmatic layering. Both of these rocks are subjected to partial melting eventually giving rise to the Production of a basic magma. Serpentinization of these ultramafics has taken place during the Alpine orojenesis.

I. İNTRODUCTİON

Recent investigation in the Hatay area showed that the mode of formation of the Kızıldağ ultrabasic massif is quite different from the hypotheses suggested in the previous years. Detailed geological and petrological Studies of the ophiolites occurring in this area, showed that the ophiolites may have well been developed along the mid-ocean ridges of the Tethys (E. Çoğulu, 1973). Troodos Massif in Cyprus, the Kermanshah and Neyriz regions of Iran, as well as Oman Ranges of East Arabia are also composed of ophiolites showing similar features (Moores & Vine, 1971; Ricou, 1971; Reinhard, 1969). Based on these observations, it may be presumed that the ophiolitic belt extending from Cyprus to the Oman belts (through SE Turkey, Kermanshah and Neyriz areas in Iran), which extend over 3,000 km, is in fact a part of the mid-ocean ridge of the Tethys.

Ultrabasic rocks constitute the majör part of the Hatay ophiolitic belt with respect to other basic units. Ophiolites were deposited at the sea floor during Upper Cretaceous. A stress zone, favoring the development of ophiolifes in the area, was formed as a result of southward movement of the Afro-Arabian plate prior to Maestrichtian times. The northward movement of the same plate in Maestrichtian resulted-in the formation of SE Anatolian Folds as the Kızıldağ Massif was thrusted in the NW direction.

II. CLASSIFICATION OF BASIC-ULTRABASIC MASSIFS AND THEİR FEATURES

Ultrabasic rocks showing different geological settings, mineralogical compositions, structural and textural features, as well as mode of formation, can be found in different massifs. Thus, attempts that have been made to classify these massifs remained unconclusive for years.

Thayer (1960) grouped these massifs into two, namely stratiform and Alpine-type massifs.

During the following years, various authors (such as Rost, 1968; Wyllie, 1969 & Den Tex, 1969) based their classifications on the genetic considerations. Classification of Den Tex, is given below:

1) Non-orogenic ultrabasic massifs

2) Orogenic ultrabasic massifs

a) Ophiolitic massifs

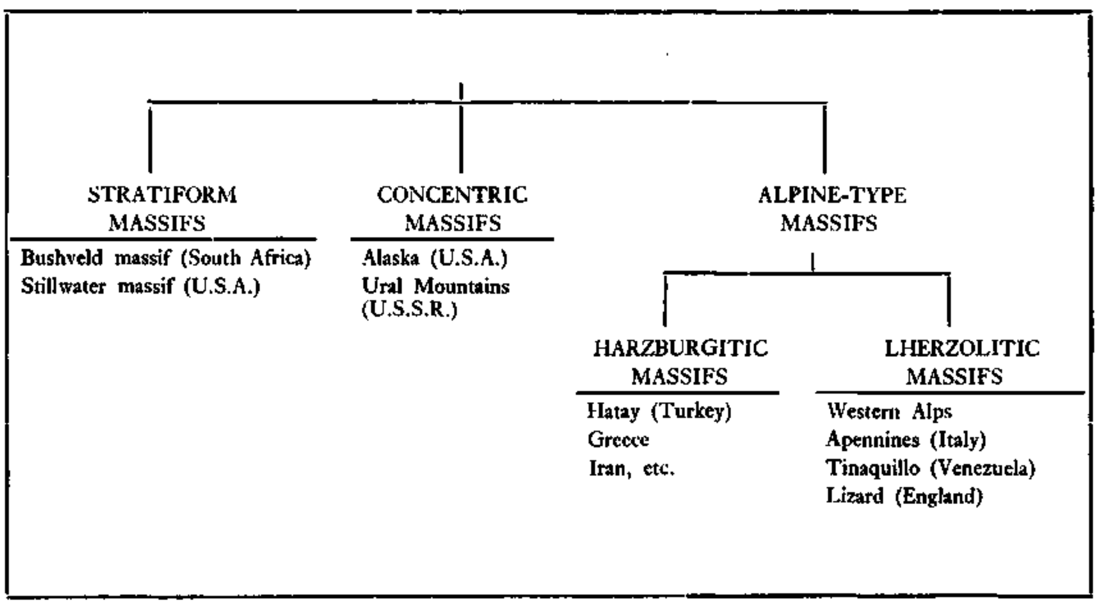
b) Root-zone massifs

Although these groups, seem to be diverse, Studies carried out in this respect showed that they, in fact, complement and correspond to each other. Non-orogenic and orogenic massifs referred to in the Den Tex's classification eventually correspond, respectively, to Thayer's stratiform and Alpine type complexes.

The majority of authors have agreed that the massifs can be well classified into three groups, namely, stratiform massifs, concentric massifs and Alpine-type massifs (Table 1) (Wyllie, 1969; Jackson & Thayer, 1972).

Table - 1

Classification of basic-ulrabasic massifs



The features of these massifs, which show considerable difference in respect to their mode of occurrence, structural and textural properties, mineralogical and chemical composition and mineral deposits contained, are summarized in Table 2.

The most striking feature of the Tables 1 and 2, is that the alpine-type massifs can be subdivided into two groups: harzburgitic and Iherzolitic. The Hatay-Kızıldağ ultramafics are included into the harzburgitic sub-group of ultrabasics (E. Çoğulu, 1973).

The fact that the serpantinite-gabbro-diabase occur in the area under investigation shows that they are genetically related. To explain this relationships, a number of hypotheses were suggested by various authors since the turn of this century (e.g. Suess, 1909; Benson 1926; Steinmann, 1927). The most important, of those, can be listed as follows:

1. Alpine-type ophiolitic rocks were formed as a result of the fractional crystallization and deposition of basic magma flowing at the bottom of the ocean (Dubertret, 1955; Brunn, 1954; Borchert, 1961).

Table - 2

Comparison of basic-ultrabasic massifs

	Stratiform massifs	*Concentric massifs*	*Alpine-type massifs*
Structural shape	Lopolith	Concentric Cylindrical	Irregular. Lensoid tectonic slices. Diapiric cones.
Structural setting	Intrusive	Intrusive	Tectonic emplacement. Marginal zones are faulted and serpentinized.
Age of emplacement	Lower Precambrian to Holocene	Devonian to Middle Cretaceous	Upper Precambrian to Tertiary
Country rock	Metamorphic or basaltic terranes	Metamorphic series or eugeosynclinal orogenic belts	Orogenic belts in the eugeosynclinal sediments and island arcs.
Metamorphic effects	Very strong contact metamorphism	Strong contact metamorphism	Contact metamorphism is generally absent excluding some massifs.
Characteristic rock types	Harzburgite Orthopyroxenite Norite Two-pyroxene gabbro Anorthosite	Dunite Wehrlite Pyroxenite Two-pyroxene gabbro Tonalite	I - Harzburgitic subtype: Harzburgite Dunite Gabbro II - Lherzolitic subtype: Lherzolite (with spinel-plagioclase-garnet)
Structure	Layered	Concentric	Foliation Lineation Magmatic layering
Texture	Cumulus textures Seldom lineation	Cumulus textures Mush flow textures	Tectonite fabrics. Recrystallization textures.
Mineral deposits	Chromite Titaniferous magnetite Copper-nickel sulfides Platinum sulfides	Titaniferous magnetite Native platinum	Chromite Platinum

2. Alpine-type ophiolites are in fact tectonic imbricate structures snapped from the earth's crust and mantle (De Roever, 1957; Hess, 1965).

3. Alpine-type ultrabasics were formed in the earth's mantle and were partly melted during their ascension within it. Gabbros and diabases are the derivatives of basic magma formed as a result of partial melting (Vuagnat & Çoğulu, 1968; Maxwell, 1969; Reinhardt, 1969).

4. Viewpoints of recent investigations, hovvever, seem to agree that the peridotites can only be formed in the earth's mantle, but controversial ideas concerning the emplacement of these rocks in the crust stili exist. Heterogenous character of the mantle should be held responsible for the occurrence of great variety of peridotites. Harzbufgitic massifs were derived from the oceanic crust, whereas Iherzolitic massifs originated from the mantle below the continents (Jackson & Thayer, 1972; Nicolas & Jackson, 1972).

Recent Studies showed that the Hatay ultramafics are a part of the mantle below the Tethyan Sea. Based on these Studies, ultrabasic rocks occurring in the area under investigation can be divided into two groups (Çoğulu, 1973):

a) Ultrabasic tectonites

b) Ultrabasic cumulates

General features of these groups, in respect to their mineralogical composition, structural and textural features, as well as their geological evolution, show considerable variations; they are discussed in Table 3.

Table - 3

Comparison of the observed features of the ultrabasic rocks occurring in the Hatay area

	Tectonites	*Ultrabasic cumulates*
Characteristic rock types	Harzburgite Dunite	Lherzolite - wehrlite Feldspathic peridotite Dunite Pyroxenite
Structure	Foliation Lineation Isoclinal folds	Magmatic layering Gradual transition into gabbro
Texture	Blastomylonitic	Cumulates textures Poikilitic textures
Vein rocks	Feldspar veins Pyroxene veins Pegmatite veins Diabase dikes	Feldspar veins Pegmatite veins Diabase dikes Rodingites
Mineral deposits	Chromite Asbestos	Chromite Asbestos

III. ULTRABASIC TECTONITES

Ultrabasic tectonites, which are in fact the materials of the earth's mantle, attained their present structural and textural properties as a result of tectonic processes. They are mainly composed of rocks showing harzburgitic composition. The highest parts of the Kızıldağ massif consist of rocks showing harzburgitic character. Dunite occurs in form of irregular masses, veins or bands showing boudinage intercalated with harzburgitic rocks. In places, harzburgite is irregularly scattered in the dunitic groundmass.

Microscopic analysis showed that dunite is composed of chrysolite crystals (90 % forsterite). Harzburgite also contains orthorhombic pyroxene and minör amounts of clinopyroxene and spinel crystals. Chromite occurs either in idiomorphic or xenomorphic forms. In hand specimens pyroxene can be easily seen with the naked eye. Chrysolite crystals occur in the form of f ine-grained groundmass, enveloping pyroxene crystals.

Important features which help to distinguish tectonites from the layered ultramafic rocks are the structural characteristics such as lineation and foliation. Microscopic analysis showed that they have a blastomylonitic texture. Blastomylonites develop in the orogenic zones and in deeper parts of the earth's crust.

The outstanding difference observed between blastomylonites and common mylonites is that the blastomylonites are intensively recrystallized. Thus, it may be concluded that the blastomylonites were affected by cataclasis and recrystallization. Blastomylonitic texture is made of two components:

a) Flattened remnants of the pyroxene phenocrysts occurring along the toliation planes of primary pyroxene crystals.

b) Recrystallized and fine-grained chrysolite in the aphanitic groundmass (olivine).

Foliation planes of the tectonites can be well seen with naked eye. Where recrystallization is intensive, rocks show massive texture and foliation is veiled. Microtectonic study of rock samples proved valuable for its help to define the foliation and lineation directions in the rocks.

One of the most important features observed in the ultrabasic tectonites is the traces of partial melting. Crystallization of the solutions resulted in the formation of numerous stringers in the tectonites. Vein-type rocks, on the basis of their composition, can be divided into four groups:

1. Pyroxene veins: Their thickness ranges between 1-2 mm to 10-20 cm. When traced along their Strike, transition into pegmatites can be seen, particularly where feldspar crystals are present. The boundary with the bedrock is not sharp, and they occur mostly surrounded by a zone showing dunitic composition. The length of the pyroxene crystals varies between 1-2 mm to l0 cm and the veins, in general, terminale with a single crystal sequence.

2. Feldspar veins: Veins, mainly consisting of basic plagioclase, dip toward the foliation planes. When traced along their Strike, they either terminale with a single crystal sequence or grade into gabbro-pegmatites, especially where pyroxene is present. Their length ranges between a few centimeters to several tens of centimeters. Their thickness, on the other hand, varies between 1-2 cm to 10-20 cm.

3. Pegmatites: Pegmatites occur in a groundmass consisting of basic plagioclase and pyroxene crystals. The thickness of the pegmatite veins varies between several cm to 40-50 cm. They are partly formed as a result of the *in situ* recrystallization, especially where partial melting took place. Their boundary with the bedrock cannot clearly be seen in such localities. Some pegmatites, on the other hand, are formed as a result of intrusions. Their boundary with the bedrock is very sharp. Pegmatites can be divided into two groups on the basis of their internal structural:

a. Basic pegmatites: irregular distribution of coarse pyroxene and plagioclase crystals is the main cause of the heterogenous character of the rock. The size of the crystals shows remarkable uniformity from the marginal zones to the core.

b. Zonal pegmatites: They consist of concentric zones showing identical mineralogical composition, structural and textural features.

Marginal zones, in general, show relatively more basic composition and contain coarse pyroxene, plagioclase and olivine crystals. Towards the core leucocratic zones characterized by acidic composition are found. The distribution of the zones is highly asymmetrical.

In the marginal areas of some zonal pegmatites, partially assimilated peridotitic xenolites were observed. When traced along their Strike, pegmatites grade into layered gabbro veins.

4. Diabase dikes: Diabases which irregulary intersect the tectonites, occur as dikes, reaching a thickness of l meter. Diabase dikes are surrounded by a fine-grained, chilled marginal zone. Bedrock is mostly serpentinized and crushed; it hâs been partly rodingitized or chloritized during the Alpine orogeny. Asbestos mineralization can be observed within the serpentinites enveloping the rodingites.

IV. ULTRABASIC CUMULATES

Layered ultramafics, mainly occurring in the S and SW parts of the Kızıldağ Massif, show gradual transition into the gabbros. They are easily distinguished from the tectonites, on the basis of their color, structural and textural features, and mineralogical composition. In contrast to the red color of the tectonites (a consequence of weathering), bedded ultramafics are generally marked by their yellow-green, dark green or olive-green colors. Since they were protected from plastic deformation, relative to the ultrabasic tectonites, structural features such as foliation and lineation cannot be seen. They show a well developed layering particularly in places where the effects of serpentinization and tectonic processes are weak. Their grain size, in comparison to the tectonites, is much larger. This in turn, caused their hydration and eventual conversion into serpentinites.

Ultramafic cumulates consist of intercalations of dunite, Iherzolite, feldspar-bearing peridotite and pyroxenite. Peridotite occurs in larger volumes relative to the dunite. A marked increase in the amount of feldspathic peridotite is observed in the upper parts of the zone. These rocks are characterized by the presence of disseminated feldspar crystals. Pyroxenites, on the other hand, occur in small amounts.

Olivine and clinopyroxene are the main minerals. Olivine, compared to the tectonites, is richer in respect to its iron content (80-85 % Fe).

The quantity of basic plagioclase occurring in the feldspathic peridotites is about 10 % and is generally transformed into minerals such as prehnite and hydrogarnet.

Microscopic examination of the olivine samples showed that olivine generally occurs in the form of idiomorphic crystals. Pyroxene, on the other hand, occurs in the form of hypidiomorphic grains. Olivine inclusions can be clearly seen (poikilitic texture) in rocks, especially when the grain size of the pyroxene reaches several centimeters. Basic plagioclase (80-90 % An), which was crystallized in the later stages, fills the spaces between other mafic minerals, in the form of xenomorphic grains. idiomorphic spinel minerals occur as inclusions within the olivine and pyroxene.

In the upper part of the layered ultramafics, a zone intersected by numerous veinlets can be seen in front of the transition zone into gabbros. These veinlets which attain a length of several hundred meters, are generally cut off by faults and their thickness varies between a few centimeters to 4-5 meters. In some veinlets, however, the boundary with the bedrock cannot be easily seen; these veins are formed as a result of recrystallization. The boundary of the relatively long and thick veins with the bedrock is sharp, since the rocks intruded the cracks within the peridotites. Based on the mineralogical composition four types of vein rocks were distinguished:

1. Feldspar veins are composed of basic plagioclase. The thickness of these veins reaches 10 cm and when traced along their Strike, pyroxene crystals, showing highly irregular distribution, can also be seen. Around these veins, which were formed by the resolidification of partial melts, cooling zone is not present.

2. Pegmatite veins are composed of basic plagioclase and monoclinic pyroxene. The size of the crystals ranges between several millimeters to 10 cm. Relatively larger crystals occur mainly in thicker veins. Since cooling zone is not present in the margins of the veins, it was presumed that the temperature was considerably high during the time of deposition. Based on the internal texture of the pegmatite veins, pegmatites are divided into two groups, namely, simple pegmatites and zonal pegmatites. Pegmatite veins attaining a thickness of 1-2 mm to 1-20 cm and forming a network around the peridotites are included into the first group. Variations observed in the size and distribution of pyroxene and plagioclase crystals, on the other hand, should be held responsible for the textural variations observed in the rocks. The boundaries between the zonal pegmatites and the bedrocks

are sharp. Marginal zones, in general, contain olivine and partly assimilated peridotite enclaves are also present in these zones. Systematic measurements carried out in these veins, which are mainly truncated, showed that the veins have two main strikes.

3. One of the commonest types of vein rocks observed in the layered peridotites is the diabase dikes. These dikes, which are as much as 1 meter thick, are surrounded by a fine-grained cooling zone and consist of plagioclase (andesine-labrador) and augite crystals and are characterized by their intersertal texture.

4. Peridotites were extensively serpentinized and affected by tectonic processes during the Alpine orogeny. Where serpentinization was intensive and strong, diabase dikes were converted into rodingites. Microscopic examination of the rodingites, in which remnants of primary intersertal texture can be seen, showed that pyroxene was chloritized and that plagioclases were transformed into hydrogarnets.

V. CONCLUSIONS

Recent petrological investigations showed that the temperature and pressure necessary for the formation of magma having peridotitic composition are by far above the physical conditions existing in the earth's crust. In other words, peridotitic magma can only be formed in the mantle. The intrusion of such a magma in the earth's crust will certainly cause contact metamorphic processes in the marginal zones. But in Hatay and other parts of Turkey, contact metamorphic zones cannot be seen. In contrast to this, the contacts between the ultrabasic rocks and other formations are faulted and peridotites occurring in the marginal zones of the massifs are crushed and serpentinized. These observations show that the tectonics played an important role in the emplacement of peridotites. Structural features of the ultrabasic tectonites, e.g. foliation and lineation, and recrystallization of olivine, evidently show that these rocks were affected by plastic deformation in the mantle and in anhydrous environments.

Laboratory tests carried out recently showed that the formation of basaltic magma may be due to the partial melting of pyrolite, spinel-bearing Iherzolite, garnet-bearing Iherzolite, and feldspathic Iherzolite in suitable environments within the mantle (Green & Ringwood, 1967; O'Hara, 1970; Boudier & Nicolas, 1972). Evidence of melting within the tectonites, and layered peridotites as well as vein rocks derived from these solutions, show that the Hatay ultrabasics were also affected by the partial melting processes. Layered peridotites, on the other hand, were formed as a result of fractional crystallization and deposition of basic magma which was derived from the partial melting of the tectonites. As already mentioned, there exists gradual transition between the layered peridotites and gabbros. The transition zone is represented by the gabbro layers intercalated with feldspar-bearing peridotites and show evidence indicating to the genetical relationship between the two rock groups. Recent observations made in the light of plate tectonics showed that the Hatay ophiolites were developed at the mid-oceanic ridge of the Tethys (E. Çoğulu, 1973). It may be concluded that the ultrabasic rocks occurring in the Hatay area, are composed of rock groups derived from different sources. Tectonites are slices of the earth's mantle and attained their present structure during their ascension in the form of diapir.

Layered peridotites, on the other hand, are the products of magma formed by the partial melting of tectonites. Both types of ultrabasic rocks continued to ascend during Alpine orogeny as a result of tectonic movements. Serpentinization, the formation of asbestos deposits and the Kızıldağ Massifs present features were developed as a result of this orogeny.

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