Mineral Res.Expl.Bull., 110, 61-75, 1990

# MİNERAL PHASES IN THE EDİGE OPHIOLITE BODY

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ABSTRACT.— Ediğe ophiolite body contains upper mantle and a part of crustal sequences, as a remnant of an oceanic lithosphere slice. The upper mantle sequence is composed of the primary assemblages of: olivin+ orthopyroxene + clinopyroxene + chromium spinel, in the tectonite ultramafics;and olivine + clinopyroxene + orthopyroxene in the cumulate ultramafics. The crustal sequence is characterized by the phases of: Plagioclase + clinopyroxene + olivin + orthopyroxene. Amphibole + serpentine + chlorite + prehnite + pumpellyite + sphene are the common secondary phases. The pyroxenes of the cumulate rocks are characterized by high Mg and very low contents of Na,K and Al. The plagioclase composition in the lovver level gabbros range from An40 to An90 The amount of amphibole development and albitization increase with stratigraphic height that, in the upper level gabbros the pyroxenes are almost completely replaced by amphibole and all the plagioclases are albite. Chromites of the tectonites are of po-diform type. All the evidences suggest that the mineral assemblages in various rock types of the Ediğe ophiolite body are similar to the corresponding rocks of the oceanic lithosphere. Minerals of the cumulates suggest direct crystallization from spreading ridge magma. They have undergone metamorphic reconstitution correlated with ocean floor metamorphism.

## İNTRODUCTİON

Ophiolite bodies provide important geological and geochemical evidences for understanding of formation of oceanic lithosphere at the mid ocean or back are spreading environments. The mineralogy gives supporting data to the findings of petrography and chemistry. it gives information about the subsolidus transformations and phase changes caused by the events which take place in the oceanic realm or/and orogenic zones where the ophio-litic material has been tectonically transported.

Minerals investigated in this study belong to an incomplete ophiolite body previously called Ediğe ultra-mafıc body (Tankut and Sayın, 1989) in the Ankara melange. Although general geology of the body and geochem-istry of its rocks have been described by Tankut and Sayın (1989) and Tankut and Gorton (in press), respectively, little information on the detailed mineralogy and phase chemistry is available.

This paper presents the results of electron microprobe, X-ray diffraction and electron microscope Studies of silicate minerals from the cumulate sequences, and chromites from the tectonite sequences in the ophiolite body, described above. Main objective of this investigation is to determine the compositions of the primary and secondary minerals, and to interprete the subsolidus changes in the mineral phases.

## PREVIOUS WORK

A brief review of the general geological and geochemical features of the Ediğe ophiolite body, previously described by Tankut and Sayın (in press) and Tankut and Gorton (1988), is presented here.

The body (Fig.l) has an in complete ophiolite stratigraphy (Penrose conference, 1972). it contains tec-tonite and cumulate uftramafic rocks and cumulate gabbros that, it is regarded to represent mantle and a part of the crustal sequences (Tankut and Gorton, in press) of the Tethyan oceanic lithosphere (Fig.2). Stratigraphically upper layers of a classic ophiolite, as sheeted dykes pillow basalts and sedimentary cover are lacking. The boundary between the mantle and crustal sequences are not w*ell* defıned due to the intense deformation and serpentiniza-tion.

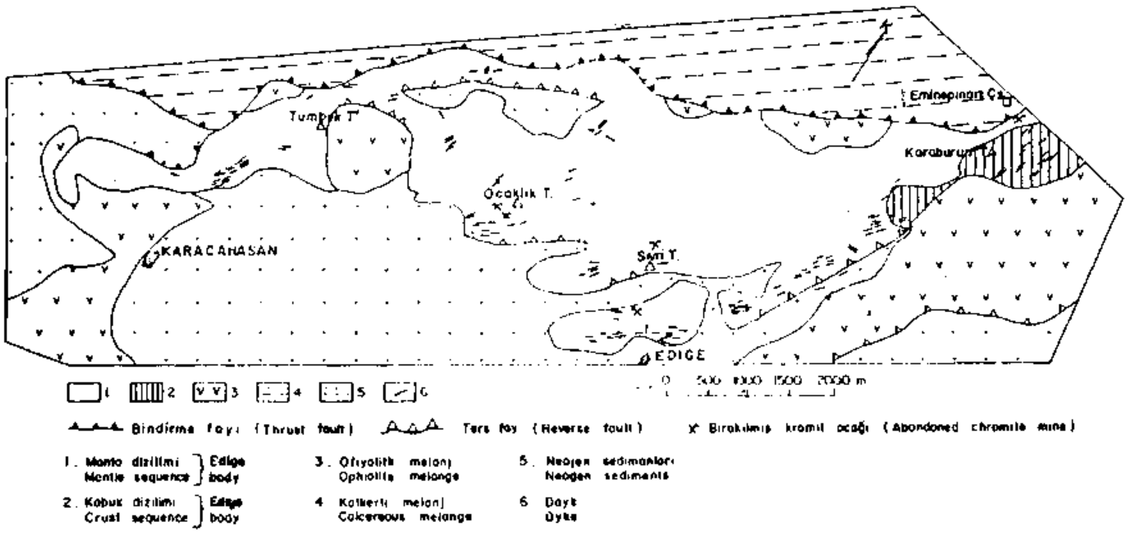


**Fig.1**– Geologic map of Edige ophiolite body. Simplified after Tankut and Sayın (1989).

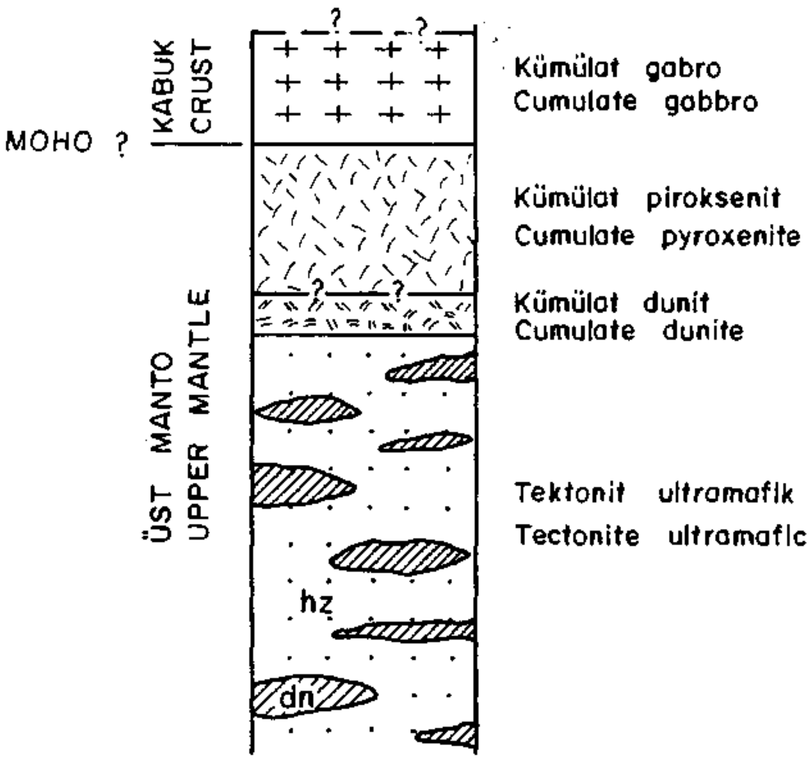


**Fig.2**– Generalized columnar section of the Edige ophiolite body.

The tectonite sequence is composed predominantly of harzburgite and lesser dunite. The latter is in the from of irregular lenses and interlayers. There are also abundant orthopyroxenite and websterite layers. Chromitite is concentrated to from the pod shaped ore bodies or occurs as thin layers within the dunite.

The cumulate sequence is thin and incomplete in the exposed outcrops. The rock types range from ultramafic cumulates to felsic differentiates. Ultramafic cumulates occur at the base of the sequence, indicating with the order of crystallization, and include serpentinized dunite, clinopyroxenite and websterite. Gabbroic members are only layered gabbros. Small lenses or dykelike bodies of only felsic material occur as being sandwiched between the gabbro layers.

## DISTRIBUTION OF MINERALS

Rocks were sampled from both tectonite and cumulate sequences. Since the body does not show its original

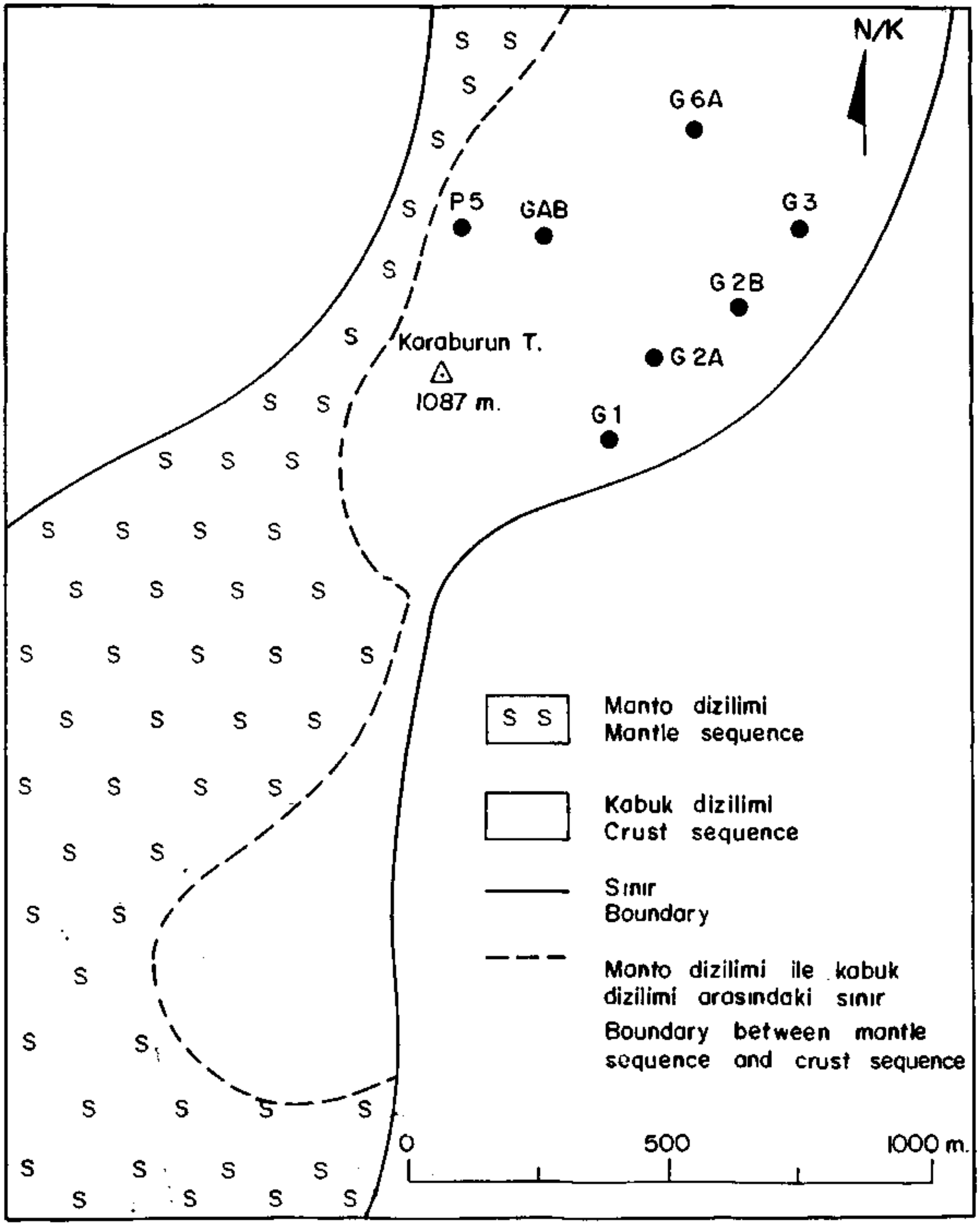


**Fig.3– Location map of Edige body.**

position, stratigraphical relations of the rocks were inferred by brief field observations (Fig.3).

### Tectonite sequence

Primary textures and mineral associations of the rocks are generally obliterated because of the intense serpentinization. Relict minerals preserved in some of the rocks have given information about the original features. In this respect, in order to discriminate harzburgite from dunite the original modal pyroxene proportions were determined from the bastites, pseudomorph of pyroxenes, since they have well preserved crystal outlines of previous pyroxenes. The best preserved mineral is chromium-spinel. It is associated with olivine and constitutes the chromitites. It also occurs as a disseminated accessory in the harzburgite as anhedral picotite and chromite, and in the dunite as euhedral chromite. Serpentine, talc, occasionally actinolite, tremolite,chlorite,magnesite and silica minerals are the common alteration products.

### Cumulate sequence

The lowest unit of the cumulate sequence is dunite. It constitutes a severely serpentinized zone between tectonite and cumulate sequences. Serpentinization obliterate the original textures and mineralogy. Pyroxenites occupy stratigraphically higher levels below the gabbros. They are clinopyroxenite and websterite and contain minerals ranging in size from medium to pegmatite. Cumulate texture is well presented by the interlocked subhedral grains of pyroxene and interstitial small grains of pyroxene and olivine between the coarser pyroxenes.

In the gabbro sequence alternation of mafic mineral rich and felsic mineral rich bands construct the layering. The rocks display well preserved cumulate texture, and deformational textures are rare. Cumulus olivine, pseudomorphosed by serpentine, plagioclase, clinopyroxene and subordinate orthopyroxene are the primary mineral phases throughout the layered gabbro sequence. Olivine is confined to the lowermost gabbro layers. Orthopyroxene poikilitically encloses the clinopyroxene and occurs as an intercumulus phase. Plagioclase, occuring in a minor amount, also appears as an intercumulus phase in the rocks of the lower levels. It is in cumulus status and occurs in a large amount in the rocks of the higher levels. The extremely low contents of REE indicate the cumulate origin of the layered rocks (Tankut and Gorton, in press). Green amphibole is a secondary mineral and the degree of its development increases with stratigraphic height. In the rocks from higher levels, almost all the pyroxenes are replaced by amphibole. Small relict pyroxene patches and abundant magnetite dots on the grains indicate the previous existance of pyroxene. Plagioclases display albitization which increases towards the upper layers. Commonly prehnite and rarely pumpellyite are present as the other secondary phases. The rocks of the felsic dykelike bodies have color index less than 5. They are composed predominantly of albite. Amphibole pseudomorph of clinopyroxene, prehnite, rarely pumpellyite and sphene are the common constituents. Their bulk rock composition displays desilisification (Si02, down to 46.50 %) and calcium enrichment (CaO, up to 24.93 %) relative to gabbros (Tankut and Gorton, in press)). Such a bulk rock composition can well be attributed to the presence of prehnite and pumpellyite. The composition is similar to those of rodingites but the absence of hydrogarnet, characteristic mineral of rodingites, excludes this possibility.

## MINERAL CHEMISTRY

Data of mineral chemistry, presented here, belong to the minerals of websterite and gabbro members of the cumulate sequence and to the chromites which are the most stable phases of the tectonite sequence.

Mineral analyses of silicates (except serpentine) were made on a computer controlled energy dispersive electron microprobe in the University of Toronto. Natural minerals were used as standards. Several plagioclases were also determined by simple optical methods and a few grains, in two rocks, by Universal stage.

were analysed in MTA laboratories by X-ray flourescent technique.

Relevant rock samples were collected from various layers. Position of the samples, in the order of increasing height, from the contact between tectonite and cumulate is, P5, G4B, G6A, G2A, G2B (Fig.3). P5 iswebsterite and the others are layered gabbros. G1 and G3 come from the felsic dyke like bodies.

## Orthopyroxene

Orthopyroxene in both websterite and layered gabbro is enstatite (Fig.4). The grains show homogeneity within the samples (Table 1). The En content ranges from 85 in the websterite to 75 in the layered gabbro.

**Table 1— Orthopyroxene composition in the cumulate rocks of Edige body**

| | *P5* | | *G6A* | |
|---|---|---|---|---|
| | *Grain 1* | *Grain 2* | *Grain 1* | *Grain 2* |
| $SiO_2$ | 54.12 | 53.64 | 54.03 | 54.57 |
| $Al_2O_3$ | 1.29 | 1.86 | 1.90 | 1.62 |
| $FeO_T$ | 6.96 | 7.47 | 15.10 | 14.66 |
| MnO | n.d. | 0.18 | n.d. | n.d. |
| MgO | 33.29 | 33.48 | 27.96 | 27.10 |
| CaO | 2.81 | 2.23 | 1.23 | 1.45 |
| $Na_2O$ | 1.69 | 1.79 | n.d. | n.d. |
| Total | 100.16 | 100.65 | 100.22 | 99.40 |
| **Structural formulae on the basis of 6(O)** | | | | |
| **Si** | 1.95 | 1.92 | 1.92 | 1.93 |
| **Al** | 0.05 | 0.08 | 0.08 | 0.07 |
| **Fe** | 0.19 | 0.20 | 0.45 | 0.45 |
| **Mn** | n.d. | 0.005 | n.d. | n.d. |
| **Mg** | 1.61 | 1.61 | 1.50 | 1.49 |
| **Ca** | 0.098 | 0.08 | 0.05 | 0.06 |
| **Na** | 0.11 | 0.11 | n.d. | n.d. |
| **En** | 84.89 | 85.02 | 74.92 | 74.51 |
| **Fs** | 9.96 | 10.65 | 22.71 | 22.62 |
| **Wo** | 5.15 | 4,07 | 2.37 | 2.87 |
| **Mg#** | 89.50 | 88.63 | 76.74 | 76.71 |

$FeO_T$ = Total FeO

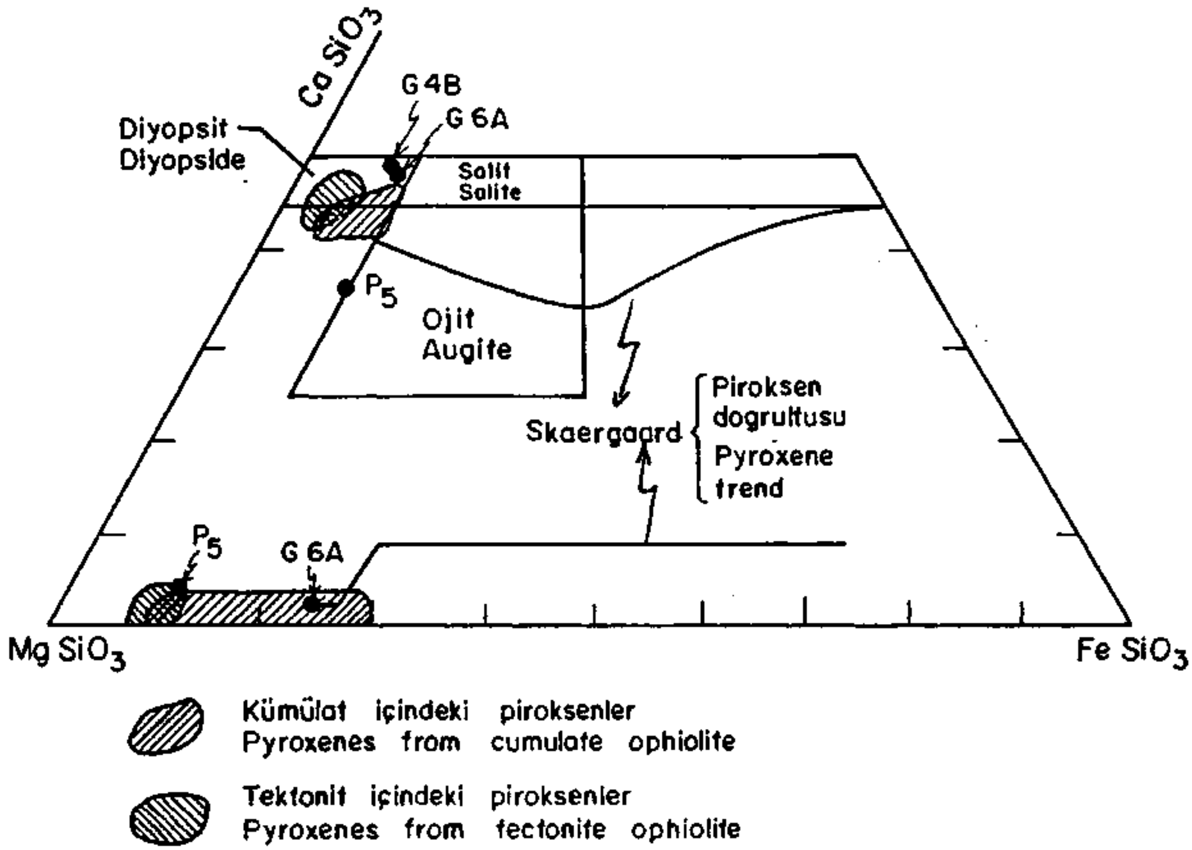


Fig.4— Pyroxene compositions from the cumulate rock of Edige body (Poldervaart and Hess, 1951). Discrimination after Coleman (1977).

The orthopyroxene of the gabbros contain more Fs (= 23) and less Wo (=2.50) relative to the websterite (Fs = 10, Wo — 4.50). That means, there is positive correlation between $Ca^{2+}$ and $Mg^{2+}$ negative correlation between $Ca^{2+}$ and $Fe^{2+}$. $Al_2O_3$ content is low and less than 2%.

Mg number $\left(Mg\ \# = \frac{Mg^{2+}}{Mg^{2+}+Fe^{2+}}\right)$ of the orthopyroxene decreases from nearly 89 in the websterite to nearly 77 in the gabbro. The coexisting clinopyroxene in the gabbro has higher Mg #: (82-84).

**Clinopyroxene**

Clinopyroxene of the gabbros show fairly homogeneous composition within the grains and within the samples (Table 2). In the pyroxene composition diagram (Poldervaart and Hess, 1951), the clinopyroxenes of the gabbros fall in the diopsite field (Fig.4). However, the "grain 2" in the sample G4B has Fs as much as 9.77 and so the clinopyroxene approaches the salite composition. Clinopyroxene of the websterite (P5) is augite. Due to the single spot analysis on one grain, information about the compositional variation within the grain and within the sample could not be obtained. The Mg of the clinopyroxenes are almost similar in the websterite (= 82) and gabbro (81.82-84.17).

**Amphibole**

Amphibole, as a secondary mineral occurs more commonly in the gabbros. The pyroxenes in the websterites show slight uralitization. Complete amphibole replacement with relict pyroxenes (mainly clinopyroxenes), exists

**Table 2 – Clinopyroxene composition in the cumulate rocks of Edige body**

| | P5 | G6A | | | G4B | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Grain 1 | Grain 1 | | Grain 2 | Grain 1 | | | Grain 2 | Grain 3 |
| | | Spot 1 | Spot 2 | | Spot 1 | Spot 2 | Spot 3 | | |
| $SiO_2$ | 52.65 | 52.22 | 52.17 | 52.55 | 52.32 | 52.36 | 51.90 | 51.83 | 52.04 |
| $Al_2O_3$ | 2.41 | 2.15 | 1.51 | 0.90 | 1.12 | 0.95 | 1.16 | 1.92 | 2.25 |
| $TiO_2$ | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | 0.18 | 0.24 |
| $FeO_T$ | 6.98 | 6.18 | 5.97 | 5.71 | 5.92 | 5.3 | 5.82 | 6.17 | 6.18 |
| MnO | 0.45 | n.d. | n.d. | n.d. | 0.17 | n.d. | n.d. | n.d. | n.d. |
| MgO | 19.09 | 15.96 | 15.54 | 15.69 | 15.39 | 15.81 | 16.11 | 15.82 | 15.83 |
| CaO | 17.86 | 24.17 | 25.03 | 25.93 | 24.58 | 25.75 | 26.83 | 23.51 | 24.10 |
| $Na_2O$ | 1.09 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| Total | 100.53 | 100.68 | 100.22 | 100.78 | 99.50 | 100.17 | 101.82 | 99.43 | 100.64 |
| **Structural formulae on the basis of 6(O)** | | | | | | | | | |
| Si | 1.90 | 1.91 | 1.93 | 1.96 | 1.95 | 1.96 | 1.95 | 1.93 | 1.90 |
| Al | 0.10 | 0.09 | 0.07 | 0.004 | 0.05 | 0.04 | 0.05 | 0.08 | 0.09 |
| Ti | – | – | – | – | – | – | – | 0.005 | 0.007 |
| Fe | 0.21 | 0.19 | 0.18 | 0.17 | 0.18 | 0.16 | 0.17 | 0.19 | 0.19 |
| Mn | 0.01 | n.d. | – | – | 0.005 | – | – | – | – |
| Mg | 1.02 | 0.87 | 0.84 | 0.34 | 0.84 | 0.85 | 0.83 | 0.88 | 0.86 |
| Ca | 0.69 | 0.94 | 0.98 | 0.99 | 0.97 | 0.99 | 0.99 | 0.94 | 0.94 |
| Na | 0.07 | – | – | – | – | – | – | – | – |
| En | 52.88 | 43.36 | 42.13 | 41.80 | 42.19 | 42.39 | 41.66 | 43.42 | 43.22 |
| Fs | 10.85 | 9.42 | 9.08 | 8.54 | 9.11 | 7.97 | 8.45 | 9.97 | 9.47 |
| Wo | 35.57 | 47.21 | 48.79 | 49.66 | 48.44 | 49.64 | 49.89 | 46.61 | 47.31 |
| Mg# | 82.06 | 82.15 | 82.26 | 83.04 | 81.82 | 84.17 | 83.14 | 82.04 | 82.03 |

in the gabbros (G2A, G2B), which are assumed to come from higher levels and rocks of dykelike felsic bodies. Beside a few remnant pyroxene patches on the grains, the lower Mg (Mg # = 68-75) content of the amphiboles than that of the pyroxenes (Mg # > 81, those of lower layer gabbros have been considered) which were supposed to be replaced, and the CaO content which is half oMhat in pyroxenes (Tables 2 and 3) confirm the secondary origin of the amphiboles (Stakes et al., 1985). Based on the analyses at two spots of a selected grain in the sample G2A, the composition within a grain seems to be quite homogeneous. It also does not change much between the different grains (Table 3). However, compositional difference is displayed between the amphiboles of the gabbros

**Table 3— Amphibole composition in the upper stratigraphical level gabbros.**

Amphibole

| | G1 | | G2A | | G2B |
|---|---|---|---|---|---|
| | *Grain 1* | *Grain 2* | *Grain 1* | | *Grain 1* |
| | | | *Spot 1* | *Spot 2* | |
| $SiO_2$ | 50.59 | 51.40 | 53.63 | 53.21 | 54.23 |
| $Al_2O_3$ | 6.03 | 4.73 | 4.74 | 5.67 | 2.19 |
| $TiO_2$ | 0.27 | 0.20 | 0.43 | 0.38 | 0.26 |
| FeO | 11.70 | 12.14 | 9.87 | 10.23 | 10.45 |
| MnO | 0.18 | 0.32 | — | — | n.d. |
| MgO | 15.45 | 15.19 | 16.52 | 16.36 | 17.29 |
| CaO | 11.59 | 10.96 | 12.35 | 12.14 | 12.66 |
| $Na_2O$ | 2.26 | 1.55 | 1.29 | 1.93 | n.d. |
| $K_2O$ | n.d. | n.d. | n.d. | 0.11 | n.d. |
| Total | 98.07 | 96.49 | 98.83 | 100.03 | 97.08 |
| **Structural formulae on the basis of 24 (O,OH,F,Cl)** | | | | | |
| Si | 7.28 | 7.49 | 7.54 | 7.42 | 7.76 |
| Al | 1.02 | 0.81 | 0.79 | 0.93 | 0.37 |
| Ti | 0.03 | 0.02 | 0.05 | 0.04 | 0.03 |
| Fe | 1.41 | 1.48 | 1.16 | 1.19 | 1.25 |
| Mn | 0.02 | 0.04 | — | — | — |
| Mg | 3.32 | 3.30 | 3.46 | 3.40 | 3.69 |
| Ca | 1.79 | 1.71 | 1.86 | 1.81 | 1.94 |
| Na | 0.59 | 0.44 | 0.35 | 0.52 | — |
| K | 0.03 | — | — | 0.02 | — |
| Mg # | 69.85 | 68.47 | 74.89 | 74.02 | 74.67 |

(G2A, G2B) and those of the felsic bodies (Gl). The latter is rich in Fe and Al. The Mg of the amphibole in the felsic dykelike rocks is as low as = 69 whereas that of the gabbros varies between 74 and 75 (Table 3). All the amphiboles are comparable in composition to actinolite (Fig.5).

Plagioclase

Microscopically plagioclases in all the rocks are unzoned. Optical determination suggest that plagioclase range from $An_{40}$ to $An_{90}$ in the lower level gabbros. The An content below 60 is most probably due to the sub-

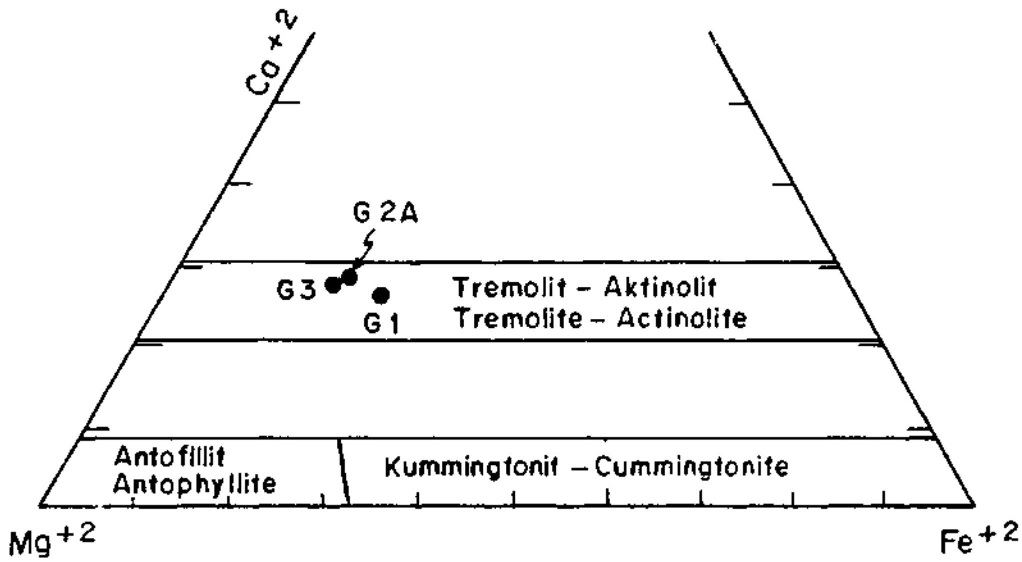


**Fig.5**— Amphibole compositions from the gabbros of upper layer, Edige body (Deer et al.,1963).

**Table 4**— Plagioclase, prehnite, pumpellyite composition in the gabbros and felsic dyklike bodies of Edige body

| | *Plagioclase* | | *Prehnite* | | | | | *Pump.*** |
|---|---|---|---|---|---|---|---|---|
| | *G4B* | *G2A* | *G1* | | *G3* | | *G2B* | *G2B* |
| | *Grain 1* | *Grain 1* | *Grain 1* | | *Grain 1* | | *Grain 1* | *Grain 1* |
| | | | *Spot 1* | *Spot 2* | *Spot 1* | *Spot 2* | | |
| $SiO_2$ | 45.85 | 69.35 | 43.33 | 43.29 | 42.54 | 43.02 | 42.03 | 36.95 |
| $Al_2O_3$ | 34.15 | 20.05 | 24.61 | 24.95 | 24.47 | 24.30 | 24.49 | 28.73 |
| FeO | 0.21 | n.d. | 1.94 | 0.90 | n.d. | n.d. | 0.50 | 4.36 |
| MgO | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| CaO | 18.25 | n.d. | 27.02 | 26.89 | 28.08 | 28.01 | 25.06 | 24.01 |
| $Na_2O$ | 1.09 | 11.57 | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| Total | 99.55 | 100.97 | 96.90 | 96.03 | 95.09 | 95.33 | 92.08 | 94.05 |
| **Structural formulae O(32)** | | | **Structural formulae 24* (O,OH) ; 28** (O,OH,$H_2O$)** | | | | | |
| Si | 8.55 | 11.87 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 5.94 |
| Al | 7.43 | 4.13 | 3.81 | 3.97 | 3.86 | 3.88 | 4.10 | 5.36 |
| Fe | 0.02 | – | 0.24 | 0.08 | – | – | 0.06 | 0.57 |
| Mg | – | – | – | – | – | – | – | – |
| Ca | 3.57 | – | 3.93 | 3.95 | 4.14 | 4.12 | 3.85 | 4.12 |
| Na | 0.43 | 4.00 | | | | | | |
| Or | 0 | 0 | | | | | | |
| Ab | 10.75 | 100 | | | | | | |
| An | 89.25 | 0 | | | | | | |

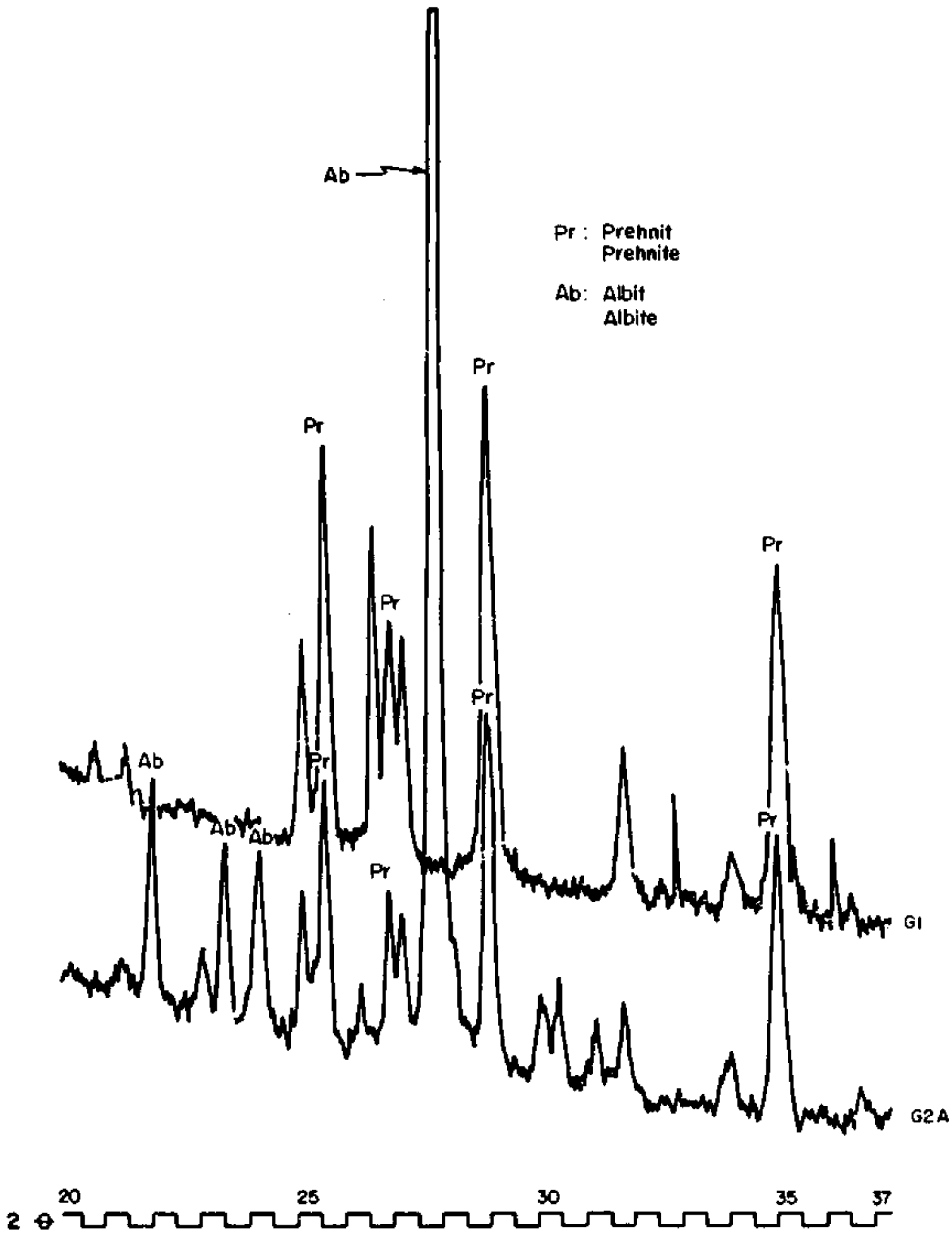


Fig.6– X–ray diffraction records of G1 and G2A samples, Edige body.

solidus equilibration. EMP analysis of one plagioclase crystal from the specimen G4B gives $An_{89}$ (Table 3) and universal stage measurement of another one from G6A was found to be $An_{40}$. All the plagioclases in the upper level gabbros represented by G2A and G2B show refractive index less than that of the Canada balsam. EMP analysis of a crystal in the sample G2A gives almost pure albite, $Ab_{100}$ (Table 3). The universal stage measurements on G2A and G2B also gave $An_4$ and X-ray diffraction patterns of the samples G2A and G2B (from the felsic dykelike rocks) indicate the presence of albite (Fig.6).

## Prehnite and pumpellyite

Prehnite exists in the high level gabbros (G2A, G2B) and dyke like rocks (Gl, G3). It exhibits its characteristic rosette form, made by the aggregation of small radiating crystals (Deer et al., 1965) X-ray diffraction records of G2A and Gl also verify the presence of prehnite (Fig.6). The results of analyses, by EMP, given in Table 4, shows that it displays its constant composition throughout the grains.

**Table 5— Chromite compositions in the chromitites of tectonite sequence of Edige body**

| | *A1* | *B3* | *C1* | *F1* |
|---|---|---|---|---|
| $Cr_2O_3$ | 60.02 | 61.76 | 60.20 | 58.76 |
| $Al_2O_3$ | 8.34 | 8.69 | 10.70 | 12.19 |
| MgO | 10.76 | 10.34 | 12.63 | 13.03 |
| $FeO_T$ | 15.86 | 15.73 | 15.79 | 14.91 |
| $SiO_2$ | 0.57 | 1.46 | 0.22 | n.d. |
| CaO | 0.40 | 0.59 | n.d. | 0.18 |
| Total | 95.95 | 98.57 | 99.54 | 99.07 |
| $Fe^{+2}O$* | 15.58 | 17.09 | 14.36 | 13.89 |
| $Fe^{+3}O_3$* | 1.16 | 0.89 | 1.71 | 1.32 |
| **Structural formulae on the basis of 32 (O)** | | | | |
| CRAT | 0.82 | 0.84 | 0.77 | 0.75 |
| ARAT | 0.17 | 0.18 | 0.21 | 0.23 |
| FRAT | 0.01 | 0.01 | 0.02 | 0.02 |
| F/FM | 0.43 | 0.47 | 0.39 | 0.37 |
| M/FM* | 0.57 | 0.53 | 0.61 | 0.63 |
| F/M | 0.75 | 0.89 | 0.64 | 0.59 |

$FeO_T$=Total FeO

* Calculated according to the stochiometry of chromite.

A1– Tümbek tepe; B3– Ocaklı tepe; C1– Edige köyü; F1– Emine pınar çeşmesi.

$$F/FM = \frac{Fe^{+2}}{Fe^{+2} + Mg^{+2}}, \quad M/FM = \frac{Mg^{+2}}{Fe^{+2} + Mg^{+2}}$$

$$CRAT = \frac{Cr^{+3}}{Al^{+3} + Cr^{+3} + Fe^{+3}}, \quad FRAT = \frac{Fe^{+3}}{Al^{+3} + Cr^{+3} + Fe^{+3}}, \quad ARAT = \frac{Al^{+3}}{Al^{+3} + Cr^{+3} + Fe^{+3}}$$

Pumpellyite has been detected by microprobe analysis. One grain in the sample G4B has a composition which corresponds to that of pumpellyite (Deer et al., 1963}.

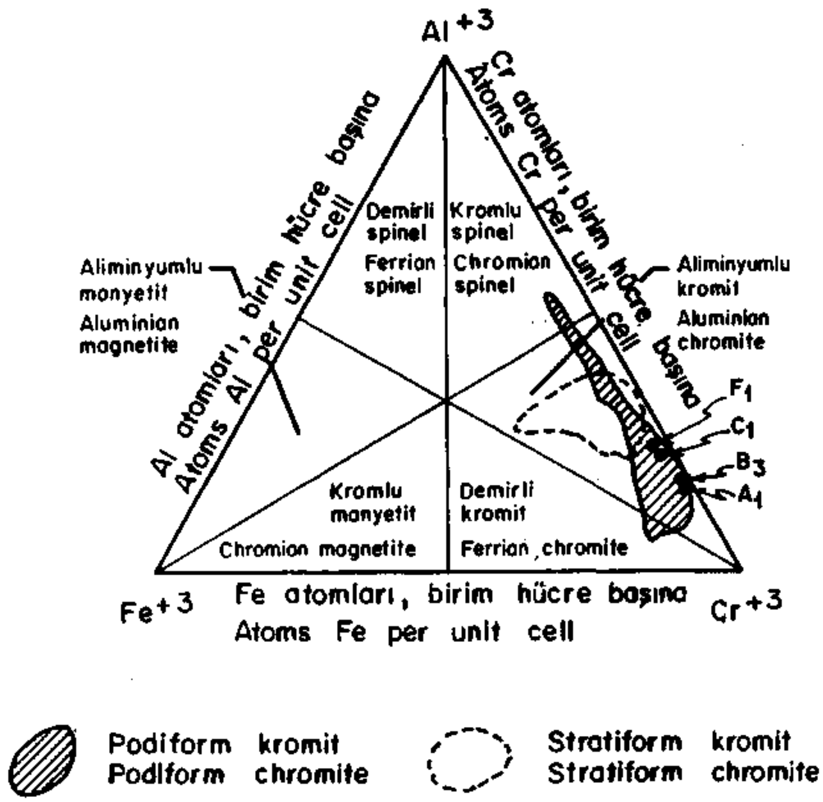


**Fig.7 — Compositions of chromites from the chromitites in tectonite sequence, Edige body (diagram after Stevens, 1944). Classification after Dickey (1975).**

Chromite samples have been collected, from the chromitites of the ore seams of various localities in the tectonite sequence, for analysis. Compositions have been determined on clean chromite powders by XRF technique. However, some silicate impurity, remained in the analyzed powder is reflected as $Si0_2$, which is up to 1.5% (Table 5).

The chromites are characterized by high $Cr_2O_3$ (58.76 % - 61.76 %) and low $A1_20_3$ (8.34 % - 12.19 %). The total FeO is almost constant around (15 %). The chromites fall in the alimunian chromite field (Fig.7) in the composition diagram (Stevens, 1944).

## RESULTS AND DISCUSSION

The primary phase assemblages of "olivine + orthopyroxene + clinopyroxene + chromium spinel " in the tectonite ultramafic rocks, and "olivine + clinopyroxene + orthopyroxene" in the cumulate ultramafic rocks characterize the mantle sequence of the Edige ophiolite body. The gabbroic rocks of the crustal sequence display the primary assemblage of "plagioclase + clinopyroxene + olivine + orthopyroxene ", the first three being the main cumulus phases in the rocks. Amphibole + serpentine + chlorite + prehnite pumpellyite + sphene are the secondary minerals. The amount of amphibole development increases with stratigraphic height that, in the upper level gabbros the pyroxenes are almost completely replaced by amphibole.

Mg-Fe relationship, represented by "Mg number" (Mg#) is one of the best indices which reflect the primary magma composition of rocks, since, Mg-Fe cation proportion changes very little during the subsolidus equilibration (Elthon and Scarfe, 1983; Elthon et al., 1985). in the crustal sequence of Edige body, similarity of the Mg numbers of clinopyroxenes in websterite(82)and gabbro (83). Suggests the same magma source for these rocks. On the other hand considerable amount of decrease of Mg #of the orthopyroxene from the websterite to gabbro can be attributed to the fractional crystallization process. Intercumulus nature of the orthopyroxene and the higher Mg # of the coexisting clinopyroxene may also imply the same process and can be explained by late crystallization of orthopyroxene. All the findings described above, support the cumulate nature of the crustal material in the Edige body.

Compositional range for orthopyroxene and clinopyroxene of the cumulate rocks (Fig.4) is comparable to those of the oceanic crust (Coleman, 1977). Both phases are rich in magnesium (Tables 1 and 2). Although the orthopyroxene of the gabbro is relatively iron rich with ferrosilite value of 23 mole %, the classic trend shown by the pyroxenes of tholeiitic magma (as Skaergaard) is not followed by the Edige pyroxenes (Fig.4). Their low $Na_2O$ and $K_2O$ (Tables 1 and 2) content indicate the depleted nature of the magma which occurs in spreading ridge

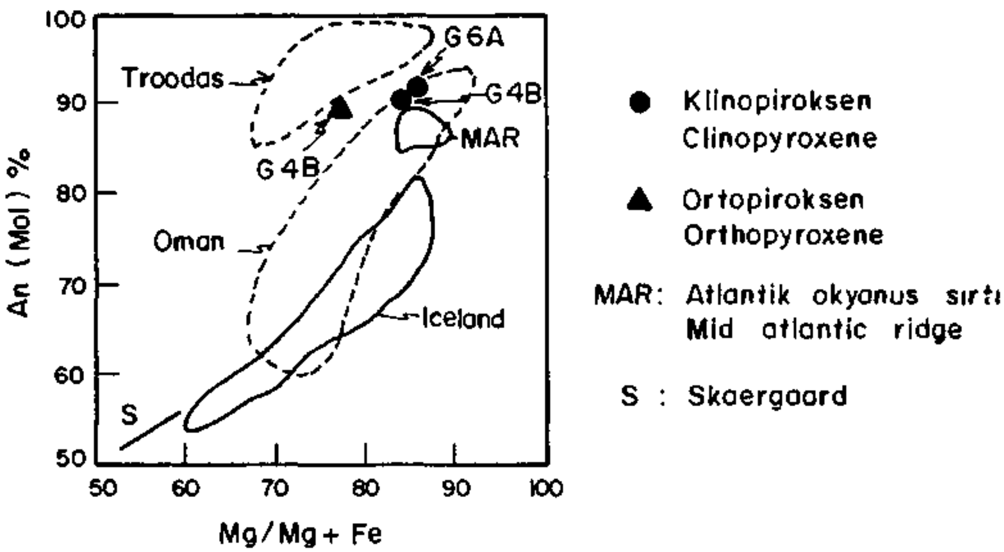


Fig.8- Compositions of coexisting pyroxene plagioclase, from the banded gabbros of Edige body (other data from Thy, 1987). Iceland data from microcrystals of alkalic glasses. The plagioclase of the G6A was determined by optical method as $An_{90}$.

environment (Malpas and Langdon, 1985). This feature therefore supports the suggestion, made by Tankut and Gorton (in press), about the depleted nature of the upper mantle as a source of the rocks in the Edige body, based on bulk rock REE contents. The low $A1_20_3$contents (Tables 1 and 2) of the pyroxenes are correlated with those crystallized at shallow depths like in oceanic crust. Plagioclase composition in the lower level gabbros range from $An_{40}$ to $An_{90}$. The composition between $An_{60}$ and $An_{90}$ are commonly reported from the gabbros of ocean floor (Prinz et al., 1976; Burns, 1985). The similarity of coexisting pyroxene and plagioclase compositions to those of ocean floor is illustrated in Figure 8. The "chromites of Edige body display properties (Fig.7) typical of podiform types (Dickey, 1975). In the structural formula, the bivalent oxide site (RO %) is occupied by 55 % - 63 % MgO (except sample B3), and this is comparable to those of podiform chromites (55% - 75%) described by Thayer (1964).

In the lower level gabbros,development of secondary ajnphibole after pyroxene, serpentine afte) olivine and low anorthite (An40) content of plagioclases, suggest sea floor metamorphism at temperatures (450°-550°C) in amphibolite facies (Coleman, 1977; Stakes et al., 1985). The higher level gabbros (G2A, G2B) are characterized by albite, complete replacement of pyroxene by actinolite and appearance of new phases as prehnite, pumpellyite, chlorite and sphene. This paragenesis indicate greenschist facjes conditions. Greenschist facies metamorphism has been reported from mid ocean ridges to appear within the upper parts of the ophiolite, including the upper parts of the gabbros (Coleman,1977).

The rocks of the felsic dyklike bodies (G1, G3) also display the same paragenesis as the high level gabbros in the Edige body. These rocks were interpreted by Tankut and Gorton (in press) to have a cogenetic relationship with the cumulate gabbros and to be probably the late differentiates of a common magma, depending on their incompatible (REE included) element contents. The lower Mg ( = 69) of their amphiboles than those of the gabbros ( = 75) support this view (Table 3). Similar bodies have been reported from other oceanic lithosphere environments (Coleman, 1977) being interpreted as the silicic differentiates (Stakes et al., 1985; Hopson et al., 1981). However, the bulk rock composition of the felsic rocks in the Edige body, show desilisification and Ca, Al enrichment (Tankut and Gorton, in press). In the light of the features described above, these rocks might have been produced from the magma as late differentiates after the crystallization of the gabbros and reconstituted by metasomatism at the sea floor.

Finally, all the evidences discussed above lead to the conclusion that the mineral assemblages in various rock types of the Edige ophiolite body are similar to the corresponding rocks of the oceanic lithosphere. The minerals of the cumulates suggest direct crystallization from the spreading ridge magma. They have undergone metamorphic reconstitution correlated with ocean floor metamorphism.

ACKNOWLEDGEMENT

Microprobe analyses were carried out at the Geology Department, University of Toronto. All the laboratory staff are acknowledged with thanks. Thanks are due to Mr. Taml Akyüz for the XRF analyses of chromites in MTA, to Mr. Akın Geven for the universal stage measurements and to Mr. Mümtaz Kibar for the XRD records.

A. Tankut is grateful to Drs.C.Cermignani and M.P.Gorton for their kind help in the EMP laboratory. Above all A.Tankut is indepted to Prof.M.,Üzümeri for his kind help and concern during her one year stay in Toronto.

*Manuscript received March 20, 1989*

REFERENCES

Burns, L.E., 1985, The border Ranges ultramafic and mafic complex, southcentral Alaska : cumulate fractionates of island-arc volcanics: Can. J. Earth Sci., 22, 1020-1038.

Coleman, R.G., 1977, Ophiolites : ancient oceanic lithosphere? : Springer-Verlag, 229, New York, Ny.

Deer, W.A.; Hovie, R.A. and Zussman, J., 1963, Rock forming minerals : Longmans Press, 5 vol., London.

Dickey, J. SJr., 1975, A hypothesis of origin for podiform chromite deposits : Geochim. Cosmochim. Acta, 39, 1061-1074.

Elton, D. and Scarfe, C.M., 1983, Highpressure phase equilibria of a high-magnesia basalt and the genesis of primary oceanic basalts : Am.Mineral.

— ; Casey, D.F. and Komor, S., 1984, Cryptic mineral-chemistry variations in a detailed traverse through the cumulate ultramafic rocks of the North Arm Mountain massif of the Bay of Islands ophiolite, New foundlend : Gass, I.G., Lippard, S.J. and Shelton, A.W., eds., Ophiolites and oceanic lithosphere, 83-97, London.

Hopson, C.A.; Coleman, R.G.; Gregory, R.T., Pallister, J.S. and Bailey, E.H., 1981, Geologic section through the Semail ophiolite and associated rocks along a Muscat-ibra transect, southeastern Oman Mountains: J. Geophys. Res. 86, 2527-2544.

Malpas, J. and Langdon, G., 1984, Petrology of the Upper Pillow Lava suite, Troodos ophiolite, Cyprus : Gass, I.G., Lippard, SJ. and Shelton, A.W., eds., Ophiolites and oceanic lithosphere, 155-167, London.

Poldervaart, A. and Hess, H.H., 1951, Pyroxenes in the crystallization of basaltic magma: Jour. Geol., 59, 472-489.

Prinz, M.; Keil, K.; Green, J.A.; Bonatti, E. and Honnorez, J., 1976, Ultramafic and mafic dredge samples from the equatorial mid-Atlantic ridge and fracture zones : Journal of Geophysical Research, 81, 4087-4103.

Stakes, D.S.; Taylor, H.P., Jr and Fisher, R.L., 1985, Oxygenisotope and geochemical characterization of hydrothermal alteration in ophiolite complexes and modern oceanic crust : Gass, I.G., Lippard, SJ. and Shelton, A.W., eds., Ophiolites and oceanic lithosphere, 199-213, London.

Stevens, R.E., 1944, Composition of some chromites of the western Hemisphere : Am.Miner., 29, 1-34.

Tankut, A.T.and Gorton,M.P.,(in press),Geochemistry of a mafic-ultramafic body in the Ankara melange, Anatolia, Turkey : Evidences for a fragment of oceanic lithosphere Moores, E., ed., Proc.Symposium, Troodos 87, Ophiolites and oceanic lithosphere,

——— and Saym.M.N., 1989, Edige ultramafik kütlesi: Turkish Journal of Engineering and Environmental Sciences; 13/2,229-244.

Thayer, T.P., 1964, Principal Features and origin of podiform chromite deposits and some observations on the Guleman-Soridag District, Turkey : Econ.Geol., 59-8, 1497-1524.

Thy, P., 1987, Petrogenic implications of mineral crystallization trends of Troodos cumulates, Cyprus: Geol.Mag., 124 (1), 1-11.