GEOLOGY AND PETROLOGY OF THE KIZILDAĞ OPHIOLITE (HATAY)

Okan TEKELİ* and Murat ERENDİL*

ABSTRACT. — In the south of Amanos mountains, a continuous ophiolite succession, the Kızıldağ ophiolite, is exposed from tectonite peridotites, through layered and isotropic gabbros to the sheeted dike complex and pillowed volcanics. The tectonites are composed mostly of harzburgites with minor dunite. The plutonic section comprises a layered gabbroic sequence of mainly wehrlite-gabbro alternations (cpx-ol and ol-cpx-pl cumulates) with minor dunite and Iherzolite, planar laminated nonlayered gabbro (chiefly ol-cpx-pl cumulates) section, an isotropic gabbro section of massive noncumulus hb-px-gabbros with plagiogranite bodies. Therefore, the plutonic sequence with minor ultramafic cumulates differs from that of the other Tauric ophiolites. The sequence also shows drastic lateral thickness and lithological differences. The sheeted dike complex is well developed and its internal structure indicates that additional spreading axes were active during the spreading process. The volcanics are composed of pillowed and massive basaltic lava flows. Cumulates show a limited cryptic variation without any considerable cryptic evolution indicating repeated primitive liquid replenishment of the magma chamber. Chemically the tholeiites of the dike and volcanic complexes are transitional between island arc and mid-ocean ridge basalts and are highly depleted in incompatible elements. Thus the Kızıldağ ophiolite is proposed to represent a kind of oceanic lithosphere produced in a slow spreading center with multiple small magma chambers developed over an already depleted mantle.

INTRODUCTION

Ophiolites of the Southeastern Turkey occur along the border folds belt forming the northern boundary of the Arabian plate. They extend along an ophiolitic zone between the Troodos (Cyprus) and the Semail ophiolite (Oman) which, at least at the first glance, poses implications about the existence of a southerly ocean, with respect to the major North Anatolian ophiolite belt, in the Eastern Mediterranean. In the western end of this zone, the second ophiolite after the Troodos is the Kızıldağ ophiolite. It is the most complete and the best preserved ophiolite among the Turkish ophiolites. The Kızıldağ ophiolite nappe has been emplaced upon the thick autochthonous Cambrian to Cretaceous shelf section that characterizes the Arabian Peninsula. Previous regional geologic works (Dubertret, 1953; Aslaner, 1973; Selçuk, 1981) dated the emplacement age of the ophiolite as Campanian-Early Maastrichtian. Delaloye et al. (1979, 1980a, 1980b) carried out several geochemical and geochronological studies and obtained an early Upper Cretaceous age for the formation of the Kızıldağ ophiolite.

Therefore the Kızıldağ ophiolite provides a valuable opportunity to study a part of the Neo-Tethyan oceanic crust and to derive important clues to contribute on the history of the Eastern Mediterranean.

REGIONAL GEOLOGY

In order to provide a reasonable framework for the general geology of the Amanos mountains, the rock units are summarized in three groups: (1) The autochthonous Arabian platform rocks; (2) The ophiolite nappes and (3) The neo-autochthonous cover rocks (Fig. 1).

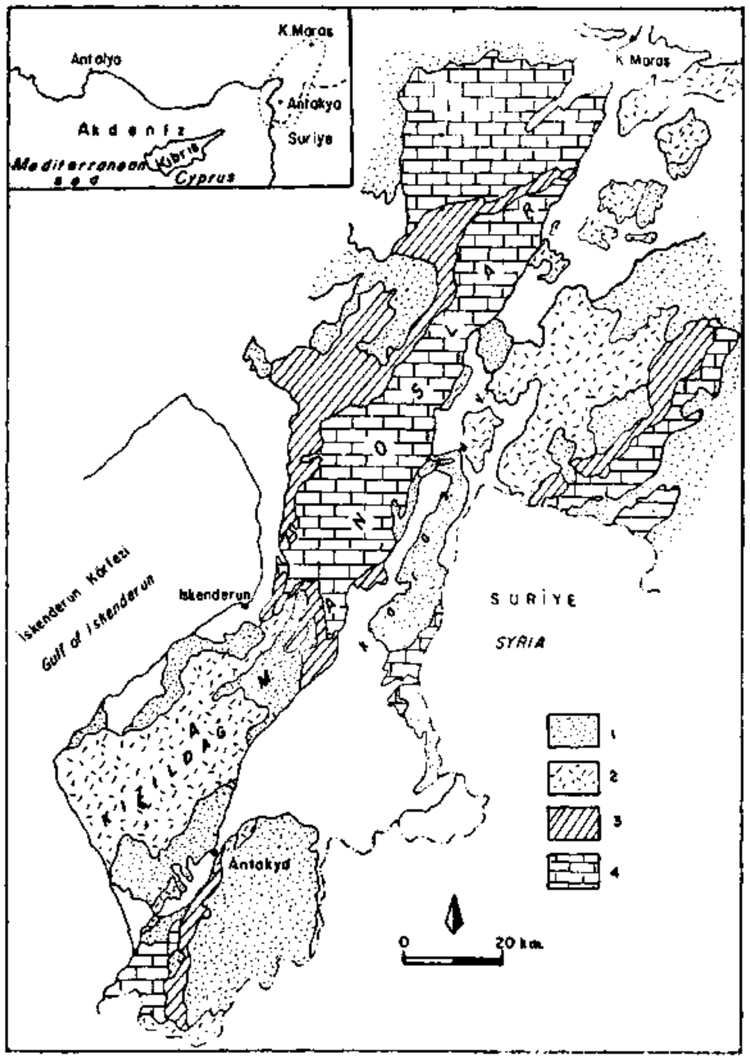

Fig. 1 - Simplified geological map of the Amanos mountains.
1 - Neo-autochthonous cover (U. Maastrichtian-Pliocene); 2 - Ophiolite; 3 - Amanos olistostrome; 4 - Autochthonous Arabian platform sediments (Paleozoic-Mesozoic).

The Arabian platform

The autochthonous Arabian platform rocks of the Amanos mountains represent the northwestern edge of the Arabian continent. The rocks of the platform sequence range from the Lowest Cambrian up to Upper Cretaceous.

The Paleozoic sequence. —The Amanos Paleozoic sequence starts with Cambrian and extends up to the Lower Carboniferous (Fig. 2). The majority of the Cambrian is of fine and coarse elastics. They include a dolomite level in the upper parts which is overlain by a section of graywacke-slate alternation. This uppermost section is the unique fossil bearing part of the Cambrian sequence (Middle Cambrian Trilobites: Dean and Krummenacher, 1961). Ordovician sequence starts with a quartzite level at the base which passes into green-brown sandstone-slate alternation in which fossil traces (Crusiana) are common (Dean and Monod, 1985). The uppermost part is of siltstone-mudstone-quartzite alternation with trilobites, brachiopoda, crinoids and tentaculitids. It is conformably overlain by the Silurian sequence of quartzite, conglomerate, siltstone and mudstone alternation rich in brachiopoda fauna. Silurian rocks are overlain by a 20-30 m thick quartzitic key horizon which indicates the beginning of the Devonian-Lower Carboniferous sequence. The rest of the sequence consists of quartzite, limestone, sandy limestone and mudstone alternations with occasional radiolarian chert beds. Any Paleozoic formation younger than Lower Carboniferous has not been differentiated yet. Therefore,the Permian period is accepted as a regional stratigraphic gap.

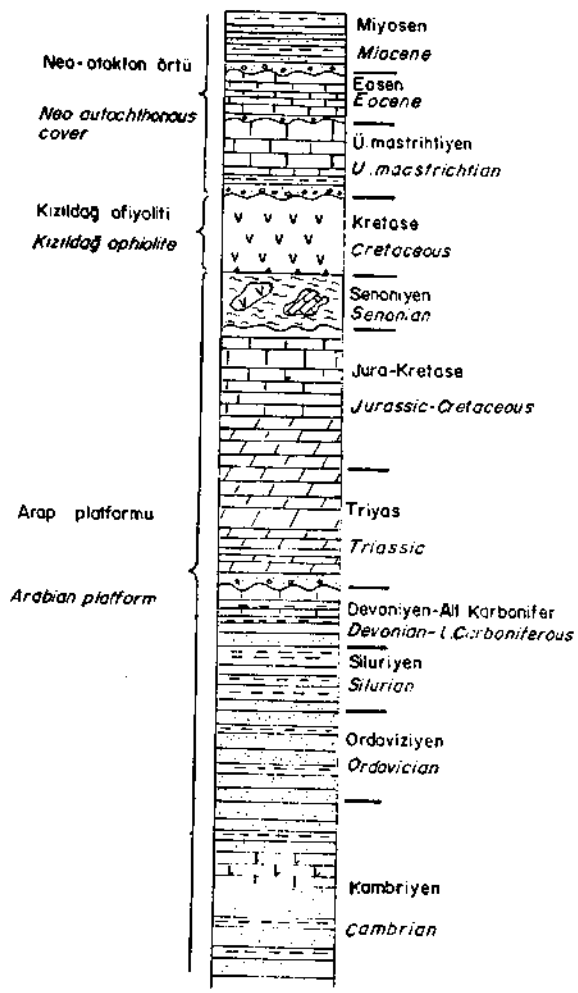

Fig. 2 - Syntethic columnar section of the Amanos mountains (See text for lithological explanations).

The Mesozoic sequence. — Transgressive across the Paleozoic elastics is an approximately 1500 m thick Mesozoic marine carbonate sequence (comprehensive serie: Blumenthal, 1938). In the south, the sequence starts with a quartzite level including a quartzite pebble bearing conglomerate at the base (Anlık quartzite: Atan,-1969). In the northern part of the Amanos mountains, the Mesozoic sequence starts with carbonates directly on the Paleozoic elastics. Although the basal clastic level is fossil-free, the immediately overlying carbonates contain Scythian fossils (A. Işık, unpublished data). The Triassic part consists of dolomites whereas the rest of the sequence is of limestones. Between the dolomites and the Jurassic limestones, frequently seen bauxite levels indicate the transition. The youngest age obtained from the limestone exposures which are surely belonging to the Mesozoic carbonate sequence is Cenomanian-Turonian (Dubertret, 1953). The Mesozoic carbonate sequence as a whole reflects tidally influenced zone of a broad shallow shelf environment (A. Aksay, personel communication, 1984).

The Amanos olistostrome. — The carbonate platform rocks are, in turn, covered by an olistostromal unit (Amanos olistostrome) containing ophiolitic blocks. This unit is exposed at only a few localities in the northern part of the Kızıldağ ophiolite as small exposures through tectonic windows. But along the Amanos range, it crops out over wide areas on both western and eastern flanks.

The matrix of the unit is of mostly sheared serpentinite. At least majority of these serpentinites should be of sedimentary origin since in thin sections most of the samples show clear clastic origin made up of serpentine particles. The serpentinite may locally alternate with or contain carbonate interbeds containing serpentine clasts. In some places serpentine debris flows with rounded pebbles of almost totally serpentinized peridotitic rocks may locally alternate with volcanic or volcanoclastic levels. These levels are found to be discontinuous or boudinized due to the intensive shearing occurred due to the nappe emplacement on top.

The blocks within the matrix show extreme dimensional variety ranging from a few tens centimeters up to kilometers. Majority of the blocks are ophiolitic rocks including mostly harzburgite, dunite and minor gabbro and pillowed lava. Olivine bearing rocks are extensively serpentinized. Apart from the ophiolitic blocks, sedimentary rocks, limestones and sandstones, occur as blocks. Limestone blocks are mostly recrystallized or dolomitic. They may also contain serpentine particles indicating that they have a different origin than the autochthonous limestones. The age of the blocks are scattered in Senonian up to Campanian (Atan, 1969; Aslaner, 1973).

The Amanos olistostrome developed on the carbonates indicates subsidence of the platform during the Senonian. Its development also indicates that the oceanic lithosphere has been uplifted and ophiolitic nappe movements have begun at the beginning of the Senonian epoch. After the development of the olistostrome with a rather regular lithological arrangement with several blocks and serpentinitic-calcerous matrix, emplacement of the huge ophiolitic nappes causes its internal deformation and chaotic structure.

Ophiolite emplacement

The Arabian platform carbonates and the Amanos olistostrome have been subjected to an intensive ophiolitic nappe emplacement during the late Senonian. This overthrusting event is one of the examples of the late Cretaceous ophiolite emplacement onto the stable Arabian platform (Stoneley, 1975) which is characteristic all along the southern ophiolitic zone up to the Semail ophiolite in Oman (Glennie, 1974; Coleman, 1981). In the Amanos region, the Amanos olistostrome with its serpentinitic matrix and ophiolite blocks witnesses beginning of the ophiolite obduction since the early Senonian. The nappe emplacement into the region should be in the late Senonian since the ophiolite nappes are transgressively covered by the Upper Maastrichtian sediments.

The neo-autochthonous cover rocks

The neo-autochthonous sediments, which were deposited after the nappe emplacement has been ceased, starts with Upper Maastrichtian (Selçuk, 1981). These shallow water marine sediments comprise a conglomeratic level at the base, with pebbles derived from all the underlying ophiolite units.

The upper levels are of sandy limestones which grade up into fossiliferous Paleocene rocks (Aslaner, 1973). Open marine sedimentation during the Eocene-early Miocene with several limestone sequences, continues with a flysch type sedimentation during the late Miocene.

THE KIZILDAĞ OPHIOLITE

The ophiolite nappes of the Amanos mountains are seen as dispersed klippes and nappes covering an area of approximately 1300 km^2. The Kızıldağ ophiolite is the biggest nappe to the south of the Amanos range. It provides excellent exposures over wide areas especially along the Mediterranean coastal cliffs. The ophiolite comprises all the ophiolitic igneous rocks and exhibits a classical ophiolite stratigraphy which consists of, from bottom to top: (1) Tectonite peridotite, predominantly harzburgite with minor dunite; (2) Layered gabbro, mainly wehrlite-gabbro alternations; (3) Isotropic gabbro, nonlayered and noncumulus cpx-gabbro; (4) Sheeted dike complex that consists of 100% diabase dikes and (5) Volcanic complex, of pillowed and massive basaltic lava flows (Fig. 3).

The Kızıldağ ophiolitic tectonites show only the high-temperature foliation. Therefore, the high-stress deformation related to the ophiolite obduction, which is quite evident in the other ophiolites of this belt (Semail ophiolite, Boudier and Coleman, 1981), is lacking in Kızıldağ. The sub-ophiolitic metamorphic rocks, which are found under most of the other Tauric ophiolites, do not exist in Kızıldağ. Also, the isolated diabase dikes, which are believed to be intruded in some intra-oceanic initial subduction zones (Parrot and Whitechurch, 1978), are not encountered in Kızıldağ ophiolite peridotites.

Tectonite peridotites

Tectonite peridotites of the Kızıldağ ophiolite occur in the highlands constituting the rugged middle parts of the massif (Fig. 4). The peridotite is the dominant rock type of the exposed Kızıldağ ophiolite and makes up about 85% of its surface exposures.

Tectonite peridotites consist of two main rock types, harzburgite (70%) and dunite (30%). Harzburgite consists of olivine (Fo_{90}), orthopyroxene (En_{90}) and spinel. Dunites are serpentinized more than the harzburgite. The tectonites exhibit a low-stress, high-temperature subsolidus deformation and a banded appearance that locally grades into massive zones. The banded tectonites consist of orthopyroxene-rich zones alternating with olivine-rich zones. Orthopyroxene foliation in the banded harzburgites is well developed (Plate I, fig. 1). Within the tectonites, there are irregular dunite zones of varying size (some are kilometric). These dunite bodies irregularly cut the harzburgite foliation. Spinel lineation is generally parallel to the foliation and banding. In the harzburgite, orthopyroxene foliation is parallel to banding, generally striking NE-SW or E-W plunging to the SE (45°). Orthopyroxene-rich bands may show isoclinal folding. In the northern part of Kızıldağ, foliation and banding show complex relations due to the intense neotectonic movements. The sense of shear is such that the upper parts of the grains are displaced northward relative to the lower parts, indicating a southward mantle flow.

Harzburgites exhibit a granoblastic texture. Orthopyroxenes usually include diopside exolution lamellae. Subsolidus deformations such as folding, kinking or ondulose extinction are evident. Linear grain boundaries forming triple junctions suggest a syntectonic recrystallization of orthopyroxenes. Brown spinels are seen as wormy grains surrounding orthophyroxenes. Olivines exhibit syntectonic recrystallization traces beside deformation larqellae and kink bands. Thus, the high temperature deformation of the tectonite peridotite is evident.

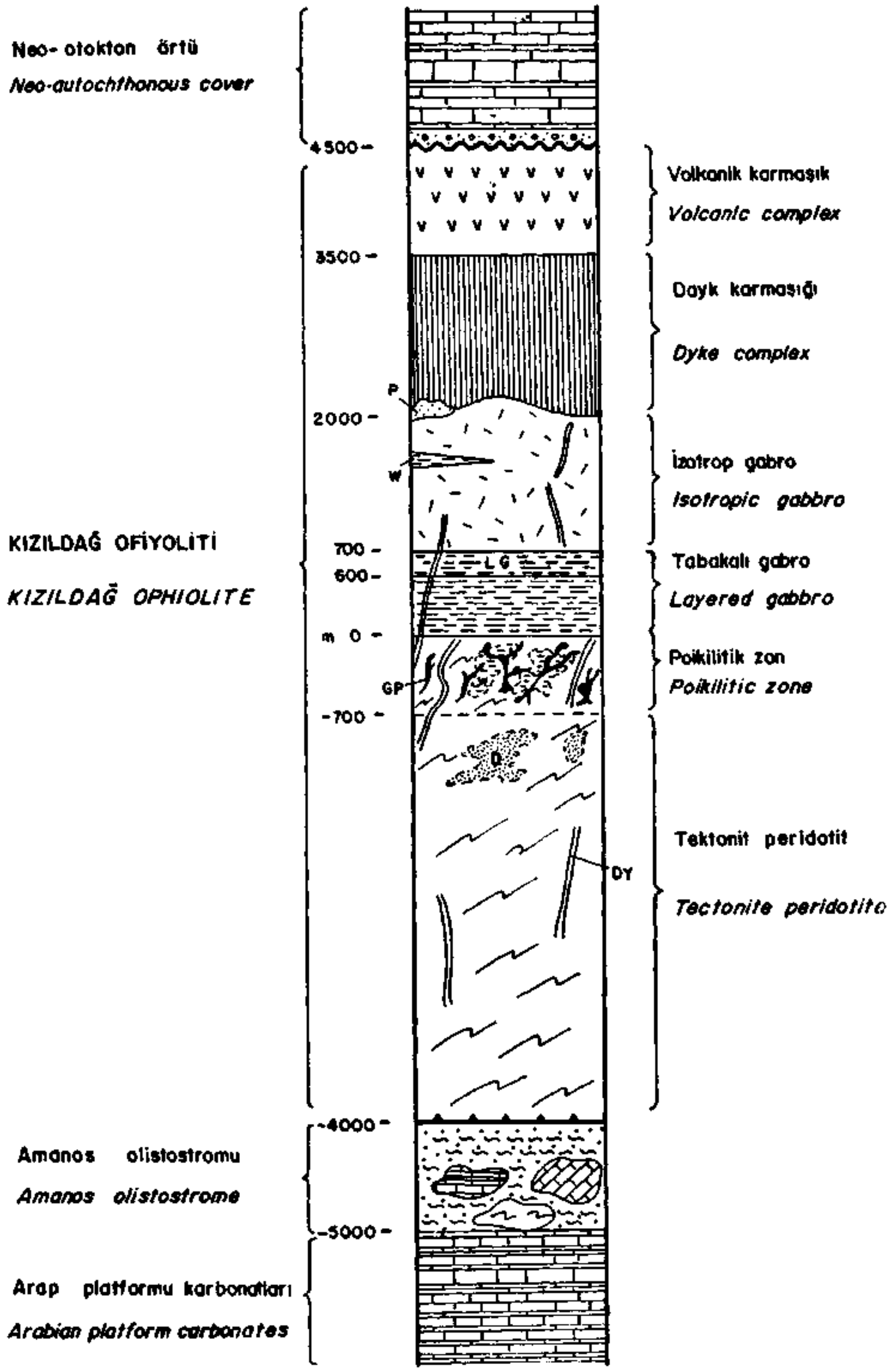

Fig. 3 - Columnar section of the Kızıldağ ophiolite.
LG - Laminated gabbro; P - Plagiogranite; W - Wehrlite; GP - Gabbro pegmatite; D - Dunite; DY-Diabase dike.

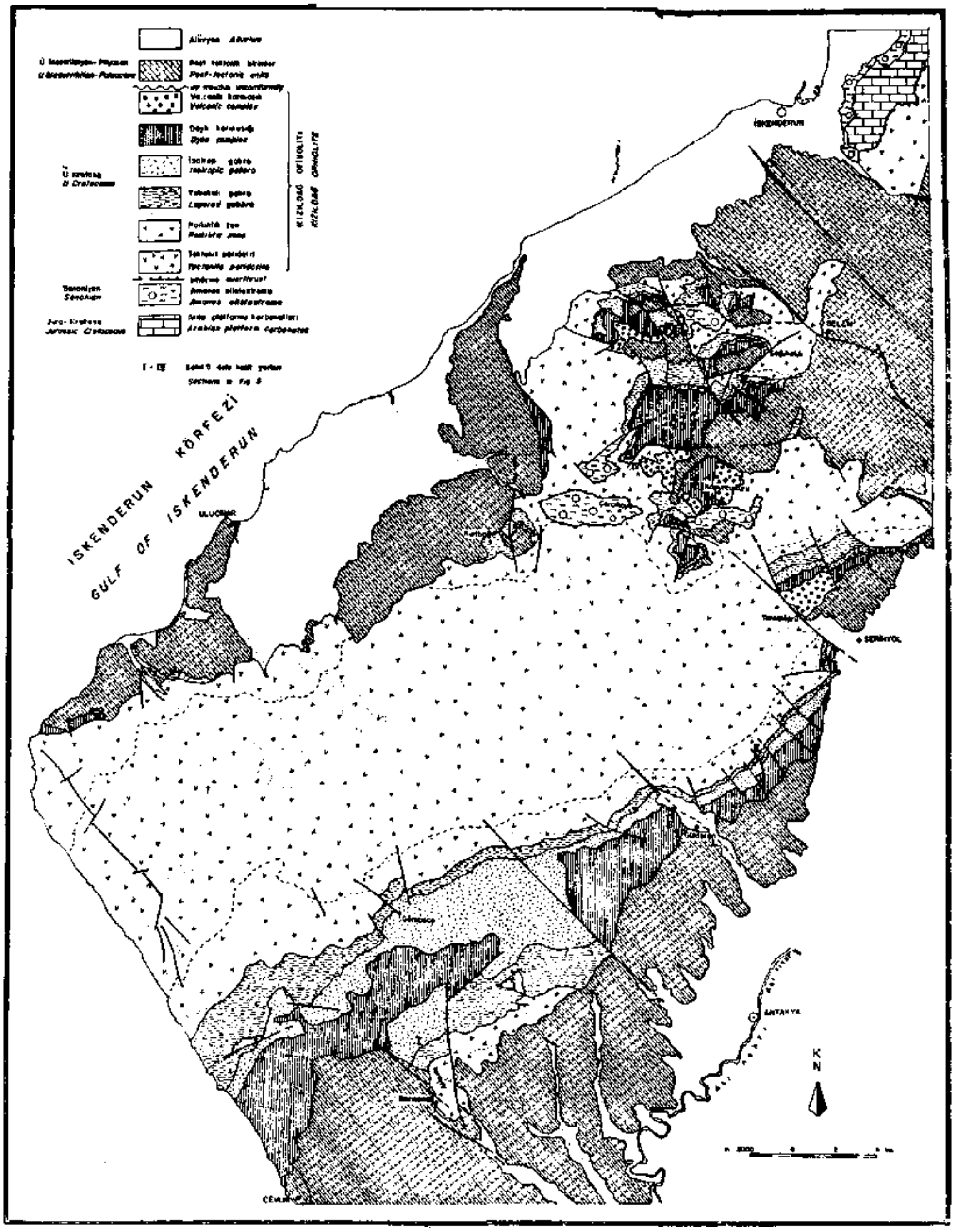

Fig. 4 - Geological map of the Kızıldağ ophiolite.

The tectonites are cut by gabbro dikes. They are usually a few cm thick (rarely 20-30 cm) with straight and sharp contacts cutting the foliation at various angles. Rarely encountered pyroxene segregations consist of concentration of orthopyroxenes (up to 2 cm) surrounded by a spinel-rich dunite cover. In the tectonite, gabbroic zones are found as irregular veins and diffuse segregations. These are generally surrounded by a dunitic cover.

Chromite in the tectonites usually occur as chramitite or as disseminated within the dunites. About 80% of the chromite bearing rocks is in the tectonites, most of which occurring in the upper levels, and the rest is in the poikilitic zone.

Poikilitic zone

The uppermost part of the peridotite tectonites forming the transition to the overlying plutonic suite is called the poikilitic zone (Fig. 4). Poikilitic texture of the rocks of this zone is striking. Lower limit of this zone is obscured but the upper contact is quite sharp. Thickness of this zone varies between 100 and 600 m depending on the overlying plutonic section thickness. This unit is widely exposed along the southeastern flanks of Kızıldağ.

This zone includes the cumulates of poikilitic texture in association with the tectonite harzburgite and dunite. It consists approximately 60% tectonite and 40% cumulate rocks and exhibits a «poikilitic» appearance with cumulate patches enclosed by the peridotite tectonites. Harzburgites may show pyroxene-rich and poor banding. Orthopyroxene foliation is not as clear as it is in the lower levels and therefore they exhibit a rather massive appearance. Zones of poikilitic texture occur as irregular bodies with diffuse boundaries mostly cutting the harzburgite banding (Plate I, fig. 2). They may also occur as strips parallel to the bands. The poikilitic rocks within the harzburgite are Iherzolite, wehrlite and websterite containing little plagioclase whereas within the dunites they are mostly wehrlite and minor melatroctolite. The other characteristic of this zone is the abundant in situ gabbro pegmatite dikes. The density of these dikes increases upwards. In the field, a genetic relation between the poikilitic cumulate pockets and the gabbro pegmatite dikes is clearly visible.

The harzburgites of this zone contain 1-2 % clinopyroxene and plagioclase occurring interstial between or around the olivine and orthopyroxene crystals. Olivine and orthopyroxene boundaries with clinopyroxene are corroded. Orthopyroxenes occur as single crystals or multigrained porphyroclasts which are intensely altered. They show deformation traces such as bending or poligonization. The dunites of this zone are of two types. The first type exhibit a typical tectonite fabric with olivine possessing kink bands. The second type includes interstial clinopyroxene and plagioclase with cumulate texture. Some of the Iherzolites develop due to the increase of clinopyroxene and plagioclase content of the harzburgite. This type of Iherzolites show cumulate and tectonite texture in association. The other type of Iherzolite is of pure cumulate origin, being olivine and some clinopyroxene representing the cumulus phase while plagioclase-clinopyroxene is the postcumulus phase. The typical rocks of this zone are cumulate wehrlite and websterite in which the texture is poikilitic. Within this zone, chromitites form discrete lenses and bodies.

Plutonic sequence

The Kızıldağ ophiolite plutonic sequence is well exposed especially along the eastern flanks of the massif. The sequence forms two regionally mappable units: layered gabbro and isotropic gabbro. In the upper parts of the layered gabbro, in fact, rocks do not show layering but lamination. This part is considered as a seperate unit to examine. Therefore the plutonic sequence comprises three zones of different features.

Layered gabbro. — The plutonic sequence of the Kızıldağ ophiolite show considerable lateral thickness and facies variation. In the southern part, for example along the Karaçay valley (Fig. 4), the 1800 m thick unit consists of 600 m thick layered gabbro. But in the northern part it is 100-200 m thick along the northeastern flanks and it continuously thins towards northwest where it is about 100 m thick (Fig. 5). Thickness variation is accompanied by lithological changes. The unit gains a striking homogeneity and loses its layered nature while it thins. Megascopic features such as ratio layering, size layering, graded bedding and slump structures result in a sedimentary appearance of the layered gabbros (Plate I, fig. 3-4). In the southern part, the unit consists mainly of gabbro and wehrlite alternation besides the interbeds of norite, gabbronorite and ultramafic cumulates such as dunite, Iherzolite, ol-websterite and websterite. Ultramafic cumulates are restricted to the basal part of the sequence. The layered sequence is characterized by well developed milimetric to metric layering. Layering results either from gradation ofthe cumulus phases (ol, cpx, pl) or from alternation of isomodal levels which are in phase and ratio contacts with each other (Plate I, fig. 4).

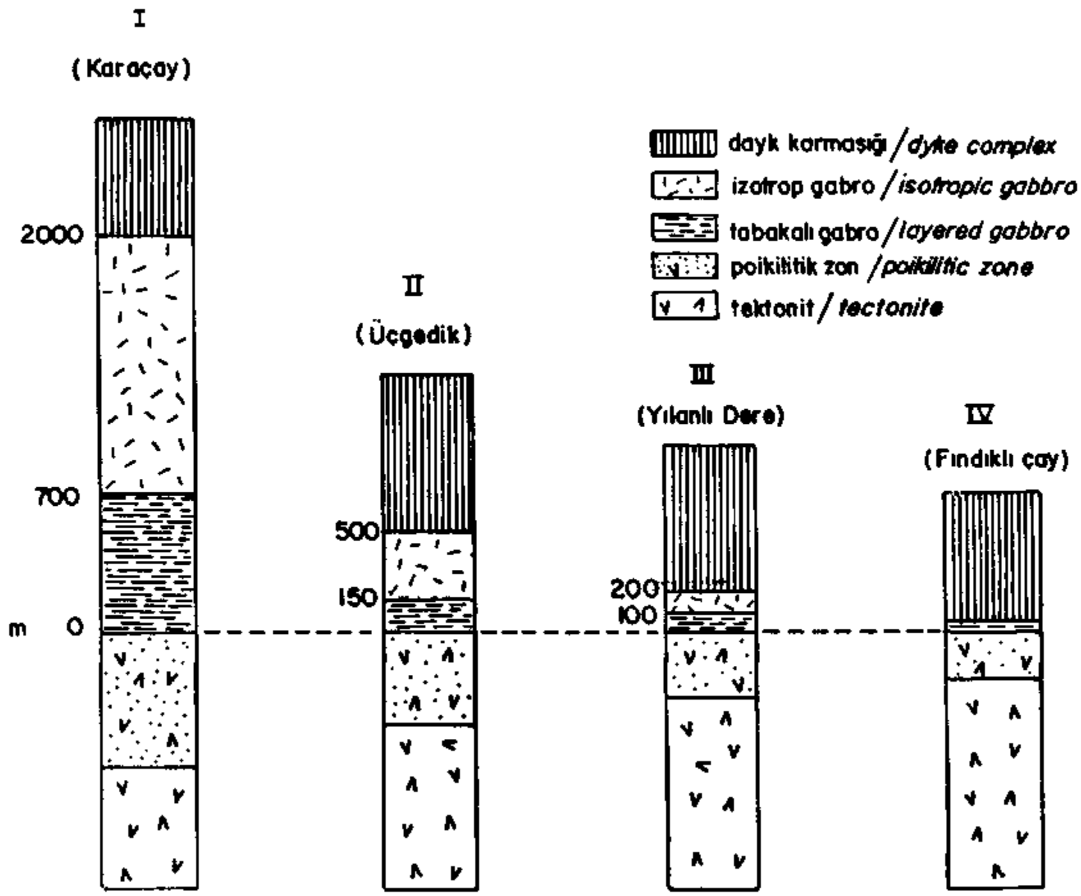

Fig. 5 - Sections showing the local differences of the plutonic sequence (Section numbers are indicated on the map, Fig. 4).

Ol-cpx-gabbro is the most abundant rock type. Cpx-gabbro and opx-cpx-gabbro occur in lesser amounts. Texture is adcumulus in the gabbros and is heteradcumulus in the olivine rich rocks. Planar plagioclase and clinopyroxene show generally well developed magmatic lineation and sometimes size grading.

Wehrlite occurs as 5-25 m thick massive interbeds along the base or as cm-dm thick layers alternating with gabbros. Thick wehrlite zones, in turn, comprise ol-and cpx-rich zones including some plagioclasev Texture is either poikilitic or granular. Ol±cpx is the cumulus, cpx+pl is the post-cumulus phase being clinopyroxene is poikilitic and plagioclase is intersertal.

Dunite occurs generally in the lower levels as irregular bodies in the thick wehrlite zones or as interbeds alternating with gabbros. Texture is ol-adcumulus and poikilitic clinopyroxene may also be present. Therefore olivine constitutes the early cumulus phase.

Lherzolite, containing little plagioclase, occurs as rare interbeds associated with gabbros. Oliopx is the cumulus whereas cpx+opx+pl is the postcumulus phase. Cpx-opx is poikilitic and plagioclase is intersertal. Texture is ol-adcumulus.

Troctolite is a rare rock type in the layered gabbro. It contains little poikilitic clinopyroxene. Texture is ol-heteradcumulus.

Along the northeastern flanks, the plutonic sequence loses its thickness considerably (Fig. 5). Layering is poorly developed and the rocks are more or less massive. Dunites and wehrlites constitute almost all the sequence. Lherzolites are rare associates. These rocks are in irregular and diffuse contacts with each other. In situ gabbronorite veins crosscut these rocks in anastomosing pattern.

In the northern and northwestern part of the massif, the layered gabbro section is locally as thin as 50 m. Layering is poorly developed. Poikilitic Iherzolite, granular wehrlite and poikilitic wehrlite-ol-gabbro alternation constitute the major lithologies. These are cut by in situ norite veins. In the Fındıklı Çay valley (section IV in Fig. 5), the sheeted dike complex merges directly into the layered gabbro section. This section consists of brown hornblende and plagioclase bearing massive Iherzolites.

Laminated gabbro. — Layered gabbros pass upwards into a zone in which the apparent layering of the lower levels of the plutonic sequence gradually dissapears. This zone is characterized by a pronounced lamination generally parallel to the underlying layering, but sometimes irregular. Lamination is a consequence of parallel arrangement of plagioclase and clinopyroxene. This laminated section develops where the gabbroic section is thick. Along the Karaçay valley, the laminated gabbro is 100 m thick and provides a transition from the layered part to the overlying isotropic gabbro. The rocks are ol-and cpx-gabbros with cpx+pl-mesocumulus and ol-cpx-pl-adcumulus textures. The unit continuously thins towards north and terminates.

Isotropic gabbro. — The uppermost part of the Kızıldağ ophiolite plutonic section is composed of gabbros showing neither layering nor lamination. This part reflects the higher levels of the magma chamber, solidified from top to bottom.

The isotropic gabbro features an extreeme grain size variation from microcrystalline to pegmatitic. Texture is hypidiomorphic and minerals show well developed compositional zoning. Therefore, a noncumulus crystallization is apparent.

In the Kara9ay valley, the isotropic gabbro reaches its maximum thickness (1100 m) and forms 2/3 of the plutonic sequence. Majority of the unit is of hb-cpx-gabbro, including hb-gabbro in the upper levels. The unit as a whole, has been subjected to an intense hydrothermal alteration. Clinopyroxene and brown hornblende are replaced by fibrous white-green actinolitic hornblende and plagioclase is saussuritized. Intensity of this alteration decreases from dike-gabbro contact downwards. Plagiogranite bodies concentrated along the dike complex-gabbro contact may include several isotropic hb-gabbro and diabase xenoliths. Some plagiogranite chonoliths intruding the base of the dike complex, with xenoliths, are also cut by later diabase dikes. Dikes derived from the underlying plagiogranite are locally abundant in the sheeted dike complex and they are crosscut by other diabase dikes. These complex intrusive relations between these rocks indicate that the roof of the chamber was in a dynamic, unstable state throughout the crystallization history of the plutonic sequence. In situ plagiogranite bodies and dikes in the lower levels of the isotropic gabbro define the sandwich horizon (Wager and

Brown, 1967). They represent the latest fractionation liquids. Quartz, feldspar, hornblende and magnetite are the main constituents. Locally, although rarely, the isotropic gabbro includes wehrlite chonoliths or sills of varying size (Plate I, fig. 5).

Along the Karaçay valley where the plutonic sequence is complete and well exposed, several samples have been collected in order to study the mineral chemistry of the constituent rocks. Sampling transect includes the gabbroic rocks of the poikilitic zone and extends up to the sheeted complex. Microprobe analyses of olivine, plagioclase, clinopyroxene and orthopyroxene from the Kara9ay samples were done using an automatized electron microprobe CAMEBAX at Nancy 1 University (accelerating voltage: 15 kv, speciment current: 20 mA, counting time: 6 sec, HENOC correction programe, natural silicate standards).

In this section of the plutonic sequence, high MgO contents of olivine and pyroxenes are characteristic (Table 1). Olivine compositions show gradual decrease in Mg content up to the layered gabbro base and limited variation in the layered part (Fo 85 - 90)- In the isotropic gabbro Fo_{75} is the mean value. Olivine and the other mineral compositions are stratigraphically depicted in Fig 6. In these profiles, mineral chemistry show only a limited cryptic variation. The limited range of this variation indicates continuous primitive magma supply during the spreading process. Olivine, pyroxene and plagioclase variation profiles exhibit the same pattern and thus indicate that these three minerals were crystallized in the same sector of the magma chamber. This feature, which was previously reported in the other ophiolites, is interpretted that gravitational crystal settling has not been occurred considerably (Pallister and Hopson, 1981).

The sheeted dike complex

The Kızıldağ ophiolite includes a well developed dike complex composed of subparallel meta-diabase dikes. The complex is a mappable unit with a consistent stratigraphic position. Along the dikes no wall rock is present so that the complex is of 100% dike rocks (Plate I, fig. 6). The upper contact of the dike complex is exposed in only a few localities in the northern part of the massif where the volcanics are discontinuously preserved. The diabase dikes cutting the volcanics increase in number towards the dike-volcanic contact to form small irregular dike complexes within the volcanics. This 30-40 m thick irregular zone provides transition from volcanics to dikes. Isotropic gabbro generally underlies the dike complex. This contact is also gradual but rather rapid with respect to the upper contact. But although the passage from dikes to gabbro occurs along a smoother contact in between, the contact, in regional sense, is quite irregular. In addition to local thickness variations of the isotropic gabbro unit, the isotropic gabbro as well as an important part of the layered gabbro may be regionally absent so that several plutons along the isotropic gabbro unit can be considered.

Dikes are chilled against the cooler host dikes. These chilled margins of the dikes are darker colored and less susceptible to weathering than their middle parts. The dikes cut each other in complex relations. But two main dike generations can be roughly distinguished simplifying this complexity (Erendil, 1984).

The dikes are fine to medium grained, sometimes phyric but mostly aphyric and nonvesicular meta-diabases. Plagioclase, clinopyroxene (augite) and magnetite are the main constituents being the second group of dikes are richer in pjagioclase content. The complex is metamorphosed hydrothermally. Greenschist facies is characteristic', but upper parts of the complex are in zeolite facies. Metamorphic facies boundaries show local irregularities (Fig. 7) depending on the intensity of the hydrothermal activities (Erendil, 1984).

Table 1 - Selected microprobe analyses of the Karaçay samples

	Olivines					*Clinopyroxenes*			
	KC8	*KC35*	*KC38*	*KC44*		*KC8*	*KC35*	*KC38*	*KC44*
SiO_2	39.41	40.66	39.67	40.27		53.05	52.53	52.62	52.53
TiO_2	0.04	0.01	0.01	0.00		0.10	0.20	0.24	0.12
Al_2O_3	0.00	0.02	0.03	0.00		1.01	2.37	2.67	2.22
FeO	20.46	11.86	14.64	14.84		4.51	3.31	3.87	4.71
MnO	0.14	0.11	0.23	0.30		0.36	0.03	0.17	0.03
MgO	40.14	47.49	44.30	44.66		16.91	17.98	17.39	17.34
CaO	0.18	0.09	0.15	0.15		23.16	21.60	21.95	22.99
Na_2O	0.06	0.00	0.03	0.01		0.27	0.08	0.32	0.09
K_2O	0.00	0.00	0.00	0.00		0.02	0.00	0.00	0.00
Cr_2O_3	0.00	0.00	0.00	0.00		0.11	0.99	0.76	0.26
NiO	0.14	0.21	0.00	0.16		0.00	0.16	0.00	0.00
Total	100.57	100.44	99.061	100.39		100.38	99.25	99.99	100.29
Fo %	77.76	87.71	84.36	84.28	En%	46.82	50.81	49.17	47.46
Fa %	22.24	12.29	15.64	15.72	Wo%	46.17	43.95	44.69	45.31
					Fs%	7.01	5.25	6.14	7.23
	Orthopyroxenes					*Plagioclases*			
	KC8	*KC24*	*KC31*	*KC48*		*KC8*	*KC24*	*KC31*	*KC44*
SiO_2	53.65	55.63	55.18	55.77		44.71	44.79	44.49	45.70
TiO_2	0.11	0.05	0.05	0.11		0.00	0.01	0.00	0.00
Al_2O_3	1.21	1.37	1.84	1.37		35.16	34.02	35.49	34.63
FeO	11.76	11.06	8.12	10.02		0.40	0.52	0.26	0.40
MnO	0.42	0.23	0.00	0.00		0.06	0.00	0.00	0.00
MgO	29.57	29.35	31.08	30.17		0.04	0.08	0.05	0.08
CaO	1.83	2.03	2.10	1.67		18.77	19.52	20.53	19.44
Na_2O	0.04	0.01	0.02	0.02		1.02	0.88	0.56	0.99
K_2O	0.00	0.02	0.00	0.00		0.05	0.00	0.00	0.00
Cr_2O_3	0.08	0.24	0.49	0.00		0.00	0.00	0.00	0.00
NiO	0.00	0.06	0.00	0.02		0.09	0.00	0.13	0.00
Total	98.67	100.05	98.88	99.15		100.30	99.82	101.51	101.24
En%	78.88	79.29	83.66	81.55	Ab%	8.91	7.53	4.70	8.43
Wo%	3.56	3.95	4.07	3.25	Or%	0.29	0.00	0.00	0.00
Fs%	17.60	16.77	12.27	15.20	An%	90.80	92.47	95.30	91.57

The general orientation of the complex appears to be EW. Chill margin statistics show that there are local anomalous one-way chilling percentages in the both north and south directions (Fig. 7). These local zones are interpreted as subcomplexes indicating secondary intrusion axes (Erendil, 1984). The overall one-way chilling percentage is to south but considerably low (3.8%). Southward chilling preference is in favour ofa northerly spreading axis with respect to the present position ofthe Kızıldağ ophiolite within the limits of this low percentage.

The rocks of the sheeted dike complex are tholeiitic basalts very poor in trace elements. They show a transitional chemistry between the mid-ocean ridge basalts and island arc tholeiites (Erendil, 1984). MORB normalized trace element and REE profiles indicate that the diabases have been originated from a highly depleted source. Low Ti and Zr values are indicative of a low spreading rate (Fig. 8). This low spreading rate deduced from chemical properties is compatible with the low crustal thickness measured in the massif (Rheid and Jackson, 1981).

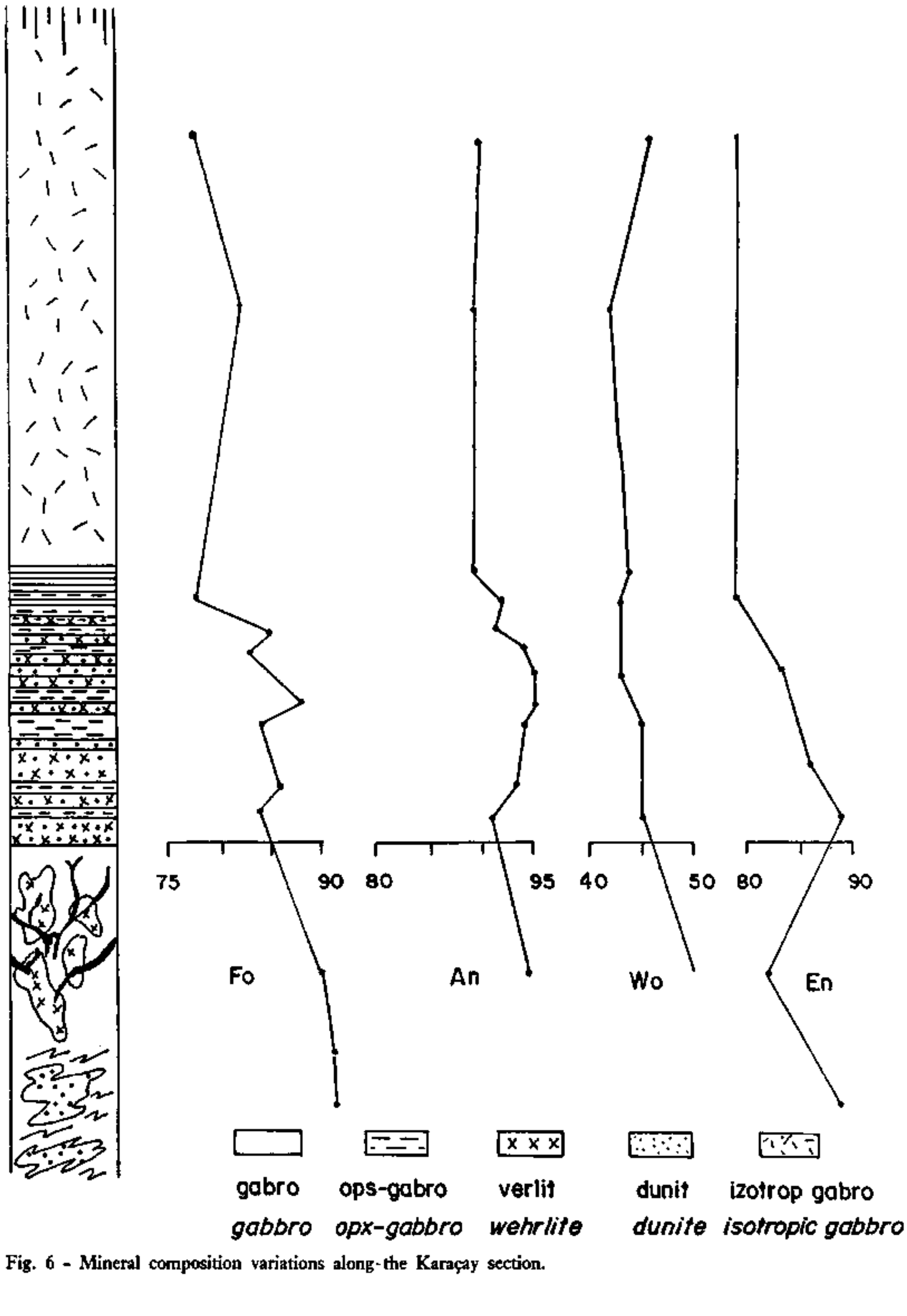

Fig. 6 - Mineral composition variations along-the Karaçay section.

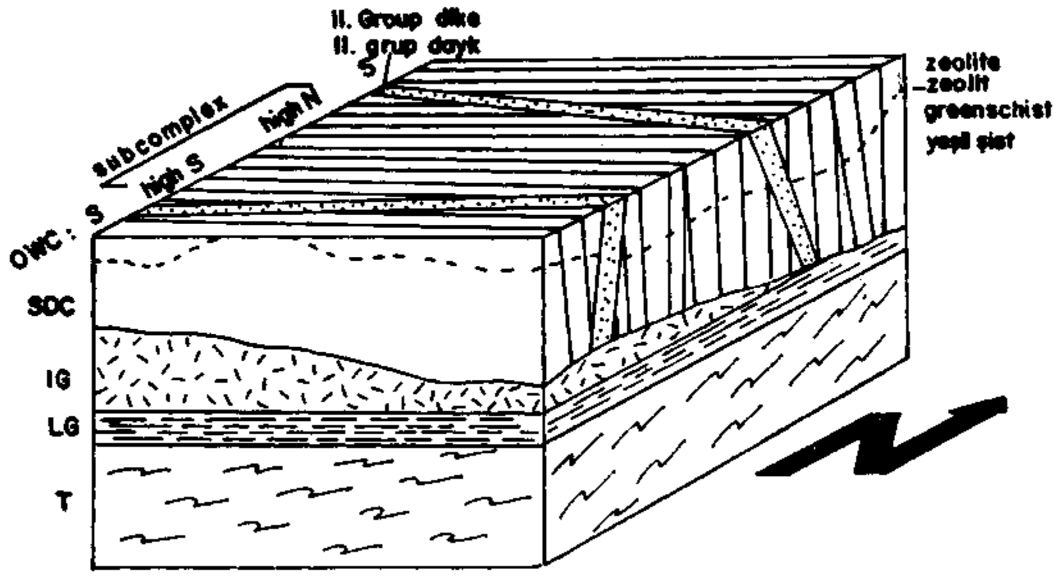

Fig. 7 - Block diagram illustrating internal characteristics of the dike complex.
OWC - One-way chilling percentage; SDC - Sheeted dike complex; IG - Isotropic gabbro; LG - Layered gabbro; T - Tectonites.

The volcanic complex

The volcanic complex of the Kızıldağ ophiolite is poorly preserved and exposed only in the northern part around Kömürçukuru village (Fig. 4). It comprises pillowed and massive lava flows with interflow and intrapillow sediments. Volcanic rocks are basalts with plagioclase, clinopyroxene (augite) and glass as their main constituents. They are hydrothermally metamorphosed in zeolite facieswith increasing temperatures from top to bottom (Erendil, 1984).

The volcanic sequence does not contain any carbonate interbeds. Instead, partly or fully manganese enriched red-brown chert beds. They occur as discrete lenses concentrated at two levels. Manganese occurs as oxide or hydroxide phases mainly as manganite or pyrolusite. Apart from the manganese, sulfides are found as concentrated in certain zones oblique or perpendicular to the volcanic layering. In these zones, forming the former conduits of the hydrothermal circulations, pyrite, chalcopyrite and malachite mineralizations are apparent.

The chemical properties of the volcanic complex is quite similar to those of the sheeted dike complex. They are transitional between island arc tholeiites and the mid-ocean ridge basalts. The complex as a whole is poor in trace and REE so that the volcanics also have a depleted magma source. Low concentrations of Ti, Zr and Y confirm the previously stated slow spreading nature of the paleospreading center (Fig. 8).

DISCUSSION AND CONCLUSIONS

The Kızıldağ ophiolite exhibits a full, except the deep sea sediments usually overlying the volcanics, ophiolite stratigraphy. Of these units, the tectonite peridotites represent the uppermost mantle during the Upper Cretaceous and records a history of mantle deformation under subsolidus conditions associated with the spreading axis environment. High-stress deformation related to the obduction mechanism or to any transform fault activity is lacking. Any subophiolitic metamorphic rock along the basal thrust contact related to the oceanic tectonics prior to emplacement upon the Arabian continental margin, do not exist in Kızıldağ. This feature, together with the lacking of isolated diabase dikes, distinguishes the Kızıldağ ophiolite from the other Tauric ophiolites. Assuming that the high-temperature deformation corresponds to asthenospheric flow related to the spreading ridge, foliation and banding as well as the sense of shear in deformed minerals in the tectonites correspond a southward mantle flow. If the asthenopsheric flow occurs perpendicular to the spreading ridge (Boudier and Coleman, 1981), the ridge axis should be oriented roughly east-west. This configuration is supported by the spreading geometry deduced from the sheeted dike complex.

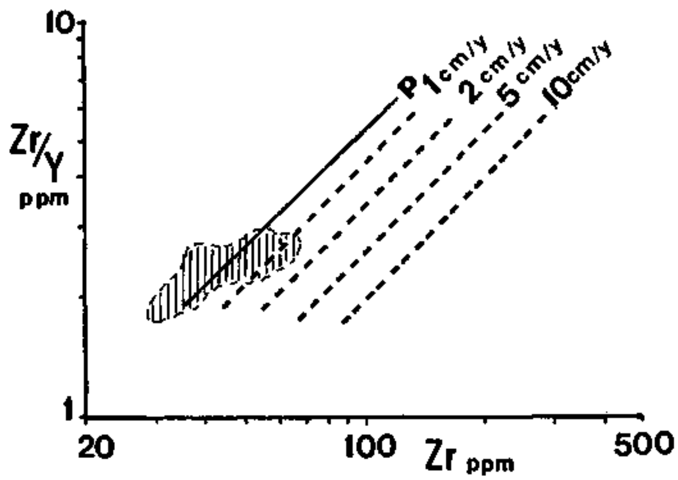

Fig. 8 - Plots of the dike and volcanic complex samples on the trace element-spreading rate diagram (Pearce, 1980).

The plutonic sequence show spatial lithological variations. The layered gabbro section is composed mainly of gabbro-wehrlite alternation with minor ultramafic cumulates at the base. Layering is well developed in the sections where the plutonic section is thick. Thin plutonic sections exhibit massive and monotonous lithological features. The isotropic gabbro section, overlying a transitional laminated zone, represents crystallization that occurred at the top of the chamber and more differentiated than the underlying cumulates. Plagiogranite is volumetrically insignificant. It occurs along the dike complex-gabbro contact and along the sandwich horizon. Mineral chemistry of the plutonic sequence show that mineral compositions vary in a limited range with a slight cryptic variation but without a significant cryptic evolution. This feature and the stratigraphy of the cumulates necessitate multiple melt injections into the magma chamber.

The sheeted dike complex formed in a 100% extensional environment and it consists of olivine-free meta-diabase dikes. Internal structure of the complex is more complex than an idealized seafloor spreading product. There are small complexes defined by the occurrence of symmetrical one-way chilling percentages. Therefore the spreading axis should be either moving during the process of spreading or accompanied by several injection axes. The low one-way chilling percentage can be a natural consequence of a spreading with multiple or moving injection axes in a true oceanic environment. But this feature may well indicate a marginal basin spreading with diffuse dike injection axes. The diabase is characteristically poor in trace and REE. Their parental magma should originate from an already depleted source.

The volcanic complex consists of pillowed and massive basaltic lava flows, now pervasively altered by low-temperature hydrothermal activity. The volcanic sequence includes only manganiferous deep sea chert and mudstones, but not carbonates, concentrated at two certain levels. Therefore the eruption should have occurred as continuous phenomenon with two passive episodes. Also, the lack of any breccia and pyroclastic zones indicates that the eruption was not vigorous. Chemical properties, being similar to those of the sheeted dike complex, indicate a transitional affinity between arc tholeiites and mid-ocean ridge basalts, with a depleted source.

The above petrochemical features of the volcanic and sheeted dike complexes can be interpreted to propose two possible oceanic spreading environments: (1) An ocean-floor spreading occurred within an already formed oceanic crust over an already depleted mantle as a new and weak ridge formation; or (2) A spreading occurred within an environment over a subduction zone.

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