Guide to Hatay geology (SE Turkey)

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GUIDE TO HATAY GEOLOGY (SE TURKEY)

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INTRODUCTION

Regional setting

The geological map included in this guide covers the whole area of Hatay (County town Antakya) including the bordering part of Syria. Particular attention is paid to the Turkish sector. The geography of the Department of the Hatay is dominated by the Amanos mountain range which runs NNE-SSW and has as boundaries the gulf and plain of İskenderun and the Arsuz plain to the NW, the Karasu valley, the Amik plain and the valley of the river Asi (known as Oronte in ancient times) to the SE (Fig. 1). The Belen Pass cuts the range in two: Gavur Dağları to the north, Elma Dağ and Kızıl Dağ to the South.

Physical geography

The relief of the Amanos range is more pronounced south of the Belen Pass, some of the peaks of the Kızıl Dağ massif approach 1800 meters (5900 feet). Numerous streams flow into the gulf of İskenderun, the Mediterranean sea and the river Asi. A humid and warm mediterranean climate supports a dense vegetation.

Road network

The roads Antakya-Belen-İskenderun, Antakya-Kırıkhan, Antakya-Yayladağ and Antakya-Reyhanlı connect the Hatay to Adana, to Gaziantep and to the Syrian town of Lattakia and Aleppo, respectively.

History of the geological study of the region

Apart from a few studies which one could class as preliminary (Frech, 1916; Ericson, 1940; Wykerslooth, 1942; 1943; Türkünal, 1950; Tendam, 1951) the Hatay province was described in a geological sense for the first time by Dubertret (1955). This region was recognized very early as one of the most favourable localities for the study of ophiolites. Thus in this guide particular attention will be paid to the ophiolites without neglecting the sedimentary formations which will be treated as autochthonous and as a cover of the ophiolites.

Apart from the work of Dubertret, many studies and much research have been carried out in this region (for example: Dean and Krummenacher, 1961; Vuagnat and Çoğulu, 1967; Atan, 1969; Janetzko, 1972; Aslaner, 1973; Parrot, 1973; Çoğulu, 1974;

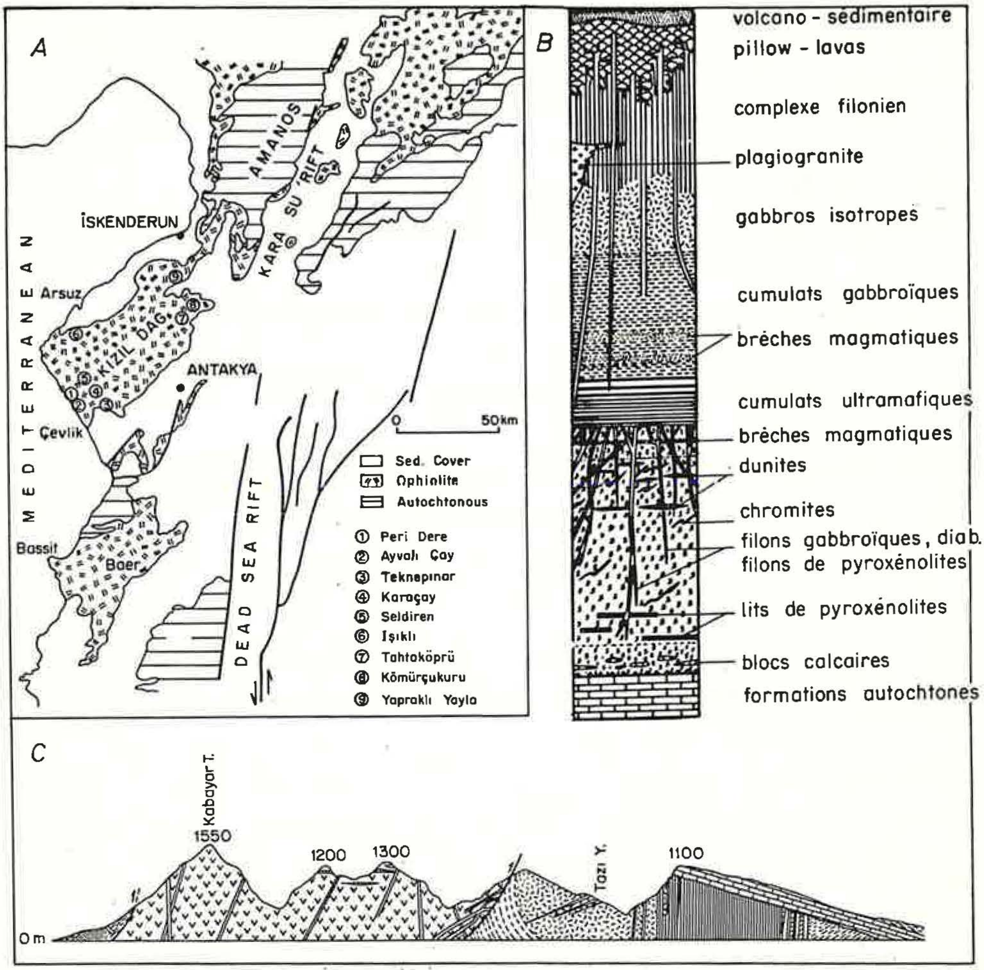

Fig. 1 -A) Situation of the Hatay Ophiolite in relation to the Dead Sea Rift and the Kara Su Rift. After Delaloye and Wagner (1984).
B) Synthetic log of the ophiolitic sequence. After Selçuk (1981).
C) Geological section through the Kızıl Dağ ophiolite massif oriented parallel to the coast line. After Selçuk (1981).

Vuagnat, 1975; Çoğulu, 1975; Çoğulu et al., 1975; Delaloye et al., 1977; 1979; Çoğulu, 1980; Delaloye et al., 1980a; 1980b; Laurent et al., 1980; Tinkler et al., 1981; Selçuk, 1981; Moritz, 1983; Yılmaz, 1983; Çapan and Tekeli, 1983; Delaloye and Wagner, 1984; Erendil, 1984; Pişkin et al., 1984). Numerous studies have been carried out by the M.T.A. (Mineral Research and Exploration Institute) Ankara and the T.P.A.O. (Turkish Petroleum Company) Ankara, but the majority of these have not been published. A new compilation has been prepared by one of us (O. Pişkin) and is presented here as a regional geological map.

THE AUTOCHTHONOUS SEDIMENTARY FORMATIONS

The geology of the Hatay and the neighbouring region of north west Syria is essentially dominated by magmatic and sedimentary rocks with very few metamorphic rocks. The majority of the magmatic rocks are ophiolitic with the remainder of effusive origin. The sediments range in age from the Lower Palaeozoic to the Quaternary. A synthetic lithostratigraphic column after Atan (1969) and Selçuk (1981) is given in Fig. 2.

Palaeozoic

At Ceylanlı and Eğribuçak the series of alternating non-fossiliferous slates, greywackes, quartzites and hornfels measuring some 500 m in thickness is transgressively covered by a Middle Cambrian formation (Atan, 1969).

Because of this transgression, Atan (1979) places these rocks in the Precambrian. Actually the existence of the Precambrian is increasingly doubtful and it is more likely that they belong to the Lower Cambrian or Eo-Cambrian as proposed by Ketin (1966).

Conglomerates, conglomeratic quartzites, orthoquartzites, subarkoses, dolomitic limestones, marly limestones, nodular slates, slates, quartz graywackes, lithic greywackes, protoquartzites make up the different lithologies of the Middle Cambrian (Acadian) dated by trilobites (*Paradoxides* sp., *Pardailhania* cf. *barthauxi* Mansuy) (Dean and Krummenacher, 1961; Atan, 1969).

Mesozoic

Triassic

The Triassic begins with a basal conglomerate discordant with the Palaeozoic. It is made up of quartzites, limestones and recrystallised dolomitic limestones and has a total thickness of 360 m (Atan, 1969). The presence of different species of Trocholina leads this author to give a Triassic age to these rocks without ruling out the Lower Jurassic.

The Albian-Cenomanian limestones are largely transgressive on the Triassic. Janetzko (1972), has considered all of the Triassic up to the end of the Cretaceous as a comprehensive series.

Jurassic

The Jurassic terrain to the south in the Keldağ region has been described by Selçuk (1981) and to the east in the Karasu valley by Dubertret (1955). No relationship with the Triassic areas has been observed. At Keldağ the Upper Jurassic (Malm) some 350 m thick, is made up of dolomitic, oolitic and sandy limestones, containing echinides, gasteropods, valvulinidae, Textularidae, Lituolidae, Ophtalmidiiae, Miliolidae, *Nautiloculina oolithica* Mohler, *Protopeneroplis striata* Weynschenk, *Protopeneroplis* sp., *Anchispirocyclina* sp., *Trocholina* sp., as well as

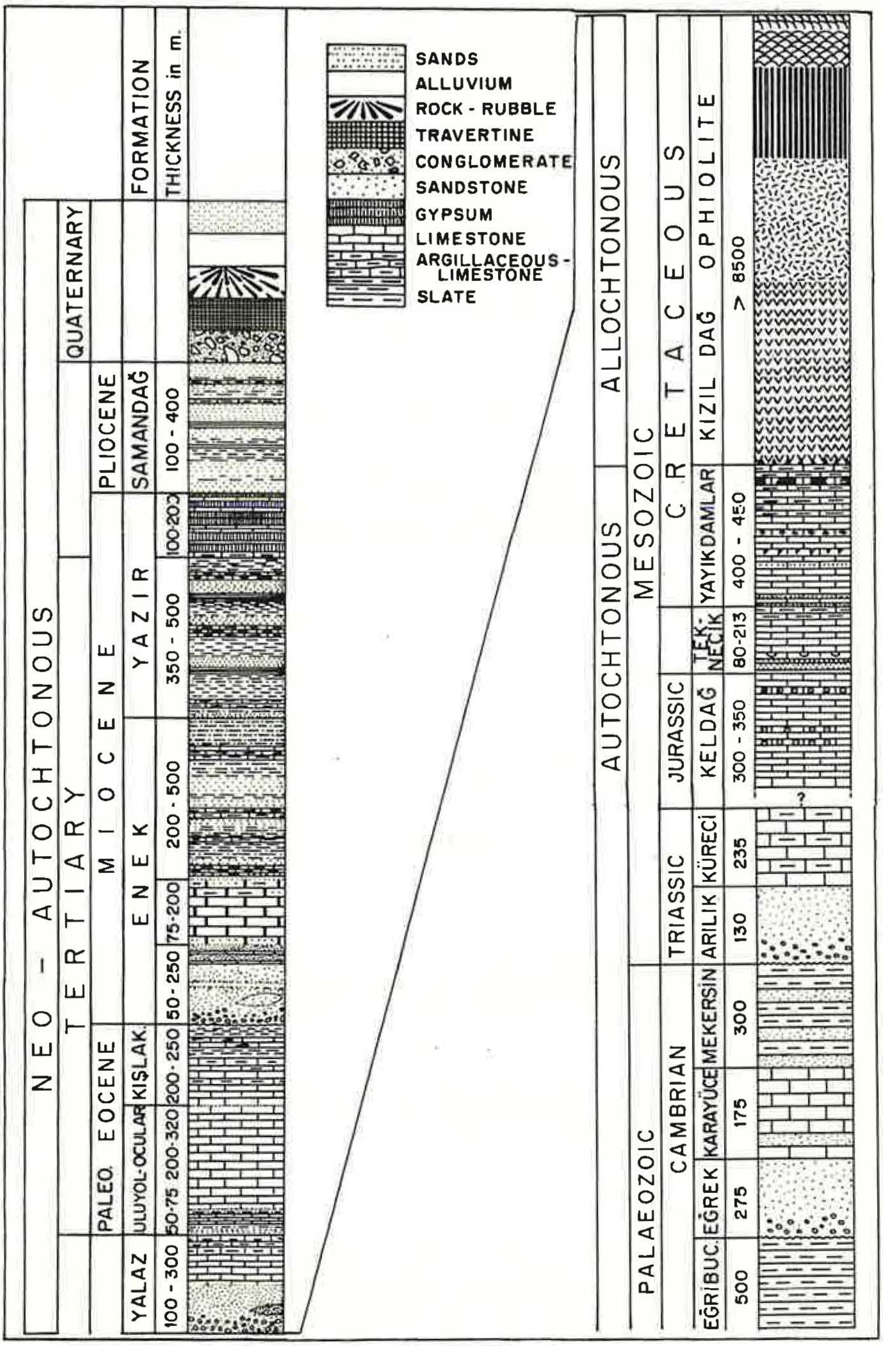

Fig. 2 - Detailed log of the ophiolitic sequence including autochthonous, neo-autochthonous sedimentary sequence as well as the ophiolite (after Selçuk, 1981 and Atan, 1969).

Textularidae (Selçuk, 1981).

Cretaceous

The Malm at Keldağ is overlain concordantly by sandstones, sandy limestones, orbitolitic limestones including levels rich in Neocomian-Albian cherts (Teknecik Karakolu formation, Selçuk, 1981), with a total thickness of 210 m containing gasteropods, bivalves and echinodermes, *Involutina* sp., *Pseudotextulariella scarsellai* (De Castro), *Melathrokerion* cf. *greigi* (Henson), *Cuneolina hensoni* Dalbiez, *Palorbitolina lenticularis* (Blumenbach), *Choffatella* sp., *Nezzezata* sp., *Orbitolina* sp., *Debarina* sp., *Baccinella irregularis* Radoicic, *Salpingoporella dinarica* Radoicic, *Valvulamina* sp., *Pseudocyclamina* sp., *Ophthalmidium* as well as Textularidae, Miliolidae and Lituolidae (Selçuk, 1981).

This is followed concordantly by conglomerates, sandy limestones bituminous limestones with flint nodules, marly limestones, marls with phosphatic, glauconitic and bituminous layers of Cenomanian-Santonian age containing gasteropods, bivalves and Hippurite fragments (Yayıkdamları formation; Selçuk, 1981). The Jurassic and Cretaceous areas are platform type sediments closely related to sediments of the Arabian platform (Al-Maleh, 1976). The last units of the Cretaceous in the Hatay form probably the basement of the overthrust ophiolite.

MAGMATIC ROCKS

In the Hatay and in north-western Syria, the magmatic rocks belong to two categories: the first part as the ophiolite suite, the second as basaltic flows.

The ophiolite

The ophiolitic series can be subdivided into tectonites, cumulates (ultrabasic and gabbroic), isotropic gabbros, sheeted complex, pillow lavas and volcano-sedimentary rocks.

Tectonites

In the Hatay the ultramafites are by far the most prevalent member of the ophiolite. According to their mineralogy, texture and fabric it is possible to subdivide them into two categories: the tectonites and the ultrabasic cumulates.

The tectonites, with an estimated thickness of 3000 m, form the highest peaks of the Kızıl Dağ massif.

The principal types of tectonites are harzburgites, dunites and chromitites.

The harzburgites are of medium grain size with quite large pyroxene porphyroblasts. They are made up of 85-95% Fo, enstatite, a little clinopyroxene and minor content of chromite and magnetite.

The dunites, of fine to medium grain size, are present as bands or as lens-shaped bodies or as large pockets. Only the latter envelope the chromitites.

The layering, foliation, lineation, isoclinal folds and the microstructures indicate different stages in the geological evolution of these rocks. The layering, which seems to be a structure preceding the plastic deformation of the tectonites and which is to a great extent masked by the serpentinization, is due to the concentration of pyroxenes with alternating layers of dunite, harzburgite, pyroxenite and chromitite.

Different deformation styles are present, isoclinal folds, minute folding and boudinage. From the microstructural study of Moritz (1983) in the area north of Keseçik, the foliation which was produced by plastic deformation, is seen as flattening planes, elongation and intercrystalline gliding of the pyroxene and olivine crystals. Foliation is oblique with respect to the layering, and coincides with the axial plane of the folds in the layering, in particular that of the isoclinal folds.

Both layering and foliation exhibit folding on a large scale, whose axes are oriented 52°W22°, 59°W27° respectively (Moritz, 1983). The lineation is visible in the alignment of the chromite grains; it is generally N-S.

In the tectonites, three types of structure are present (Moritz, 1983). Coarse grain porphyroclastic, fine grain porphyroclastic and equant equigranular. The porphyroclastic coarse grain structure is found in the tectonites up to 1500 m from the contacts with the cumulates. It is characterised by the concave forms of the enstatite, by the presence of rare interstitial clinopyroxenes, by a marked polygonisation of olivine and by a generally poor fabric.

These particularities place these rocks in the upper part of the ophiolitic ultramafites which have only undergone a weak deformation in the hypersolidus condition and at temperatures between 1000° and 1300°C (Nicolas et al., 1980).

The equigranular equant texture is seen in the dunites. The boundaries of the olivine grains are regular with a high polygonisation, with triple points. Although the fabric is weak, the common extinction of the olivines suggests a well developed lattice fabric. Such a structure is the result of a high temperature deformation (Nicolas et al., 1980).

Dykes in the tectonites

The tectonites of the Kızıl Dağ massif are intruded by pyroxenitic, feldspathic, gabbroic and diabase dykes. Only the diabase dykes have chilled edges. The pyroxenitic dykes are found in the harzburgites and the dunites and can be subdivided into two types:

a) "Intrusive", rectilinear in shape with clearly defined borders.
b) "In situ", folded and undulated (Çoğulu, 1980).

The folding of the dykes could be contemporary or posterior to their formation. The intrusive dykes are often oriented mutually parallel which would indicate injection along parallel fractures produced by tension (Reuber, 1982). As these dykes are not folded they are considered to be posterior to the "in-situ" dykes. The chronology of these two types of dykes is supported by the orientation of each with respect to the foliation of the host rock. The "in-situ" dykes being generally parallel (Çoğulu, 1980), whilst the orientation of the intrusive type is discordant with respect to the orientation of the foliation plane.

The dip of the dykes towards the north on the NW side and to the south on the SE side could be explained by the late folding on a large scale which has affected the foliation and layering.

The majority of the dykes in the tectonites have a gabbroic composition with variable amounts of feldspars. The feldspathic segregations are only found near to the contact between the tectonites and the cumulates. The country rock of the gabbroic dykes is either a harzburgite or a dunite, both of which are very varied in composition, internal structure, form and dimensions. The plane of intrusion is discordant with the foliation of the host rock. These dykes are often zoned, with each zone having a different texture and mineralogical composition. Although chilled margins are absent one often sees partially digested ultrabasic xenoliths.

Going from the tectonites to the cumulates, the number and thickness of the dykes increase with a tendency towards two preferential orientations: N60-70E, 45-60NW; N30-50W, 40-50SW.

Diabase dykes are infrequent in the tectonites. The host rock is almost always a harzburgite, highly serpentinised at the dyke contact which is always straight and clearly visible. These are the only dykes with chilled edges, proof of intrusion into a relatively cold environment. However, there is no preferential orientation.

Cumulates, isotropic gabbros and plagiogranites

In general, the tectonites which form the central part of Kızıl Dağ are surrounded by cumulates which range from ultrabasic up to gabbroic at the top of the series.

The relations between the cumulates and the tectonites are best seen along the coast. In the north (Domuzburnu, İsıklı) the oriented gabbros show a tectonic contact with the harzburgites. In the south (between Peri Dere and Ayvalı Çay) tectonized harzburgites are overlain by dunites, lherzolites, wehrlites, feldspathic peridotites and pyroxenites. This sequence has been interpreted as progressive by Parrot (1973) and Çoğulu (1975) but a sharp change in morphology and petrography is in favour of a tectonic contact. The cumulitic character of most of the textures can be established despite a pervasive serpentinization. The lherzolites are the most abundant rocks present in the sequence.

The transition from one layer to another is by a change of phase, concentration or morphology. In this series the pyroxene rich layers are more numerous than the dunite layers. The thickness of the plagiferous peridotites increases in the upper zones. The pyroxenites form one of the less prevalent units. The thickness of the layered ultrabasic cumulates varies from a few centimetres to several metres. They exhibit textures due to fractional crystallization and gravitational settling. The constituent minerals are olivine (Fo_{75-80}), enstatite-bronzite, augite-diallage, plagioclase (An_{85-90}), chromite and picotite.

This part of the ultrabasic cumulate series is traversed by numerous anastomosed pegmatitic gabbros dykes which locally give to the sequence the appearance of a magmatic breccia, a hybrid zone (Vuagnat and Çoğulu, 1967) or transition zone (Delaloye et al., 1980a). Ascending the series the ultrabasic plagioclase levels become less frequent. Near Ayvalı Çay an important E-W fault separates two blocks. In the northern one the gabbroic dykes are numerous and the southern one is made from layered gabbros.

In the Kara Çay valley, near İkizköprü, cumulates are well represented. To the south of this section feldspathic ultramafites are observed alternating with ultramafic cumulates, olivine gabbros and adcumulate gabbros. To the north adcumulate gabbros become more and more abundant.

The lower part of these layered gabbros frequently exhibits fine flow structures, cross bedding, graded bedding, isoclinal folds and magmatic slump structures. All of these synmagmatic structures could indicate that the fractional crystallization and the sedimentation was produced in a disturbed environment and probably in one or several magmatic chambers of moderate size.

The principal types of layered gabbros are melagabbros, troctolites, olivine gabbros, two pyroxene gabbros and leucogabbros. The constituent minerals are olivine, orthopyroxene, clinopyroxene, basic plagioclase and spinel.

The basin shape (orientation NE-SW) formed by the magmatic bedding of the cumulate gabbros is interpreted as primary (Çoğulu, 1975) or secondary due to the thrusting of the tectonites and the cumulates (Tinkler et al., 1981; Selçuk, 1981).

Towards the top of the gabbros, the layering gradually disappears to be replaced by a homogeneous structure (isotropic gabbros). This structural change is accompanied by a mineralogical change: the olivine and orthopyroxene disappear whilst clinopyroxenes, amphiboles (ouralite, actinote, hornblende) and plagioclase (An_{70}) become the principal minerals.

Norites, two pyroxene gabbros, gabbros, leucogabbros and amphibole gabbros are the most frequently encountered types. In the amphibole gabbros, which form the highest part of the series, one finds acidic rocks such as quartz diorite or plagiogranite. These rocks are present as small veins, dykes or sometimes as irregular bodies of variable size.

The general mineral paragenesis of the plagiogranites is quartz+albite (oligoclase - andesine)+diopside+alkali feldspar+green hornblende+chlorite+sphene+opaque minerals.

Sheeted complex

The intrusive rocks exist either as separate dykes or as a dyke complex. The former are described in the paragraph on the tectonites. The contacts between the cumulates and the sheeted complex are primary and with an increasing number of dykes one passes gradually to a dyke complex. The best outcrops are on the coast, between Teyekli Dere and Karmuşun Kayası where the thickness of the complex is of the order of 2 km. The E-W strike of the dykes is reasonably constant, their dip varies from NW to SE.

Within the sheeted complex three types of rock are distinguished: the coarse diabases, the dykes without chilled margins, the diabases with chilled margins and the fine grain basaltic diabases present as thin dykes with chilled margins. The chilled margins can be symmetric or asymmetric. The relationships between the different dykes and the host gabbro are complex ranging from juxtaposed dykes to dyke in dyke with screens of isotropic gabbro.

The dykes have an essentially tholeiitic composition (Laurent et al., 1980) and Erendil (1984) considers that the greater part of the sheeted complex was created in an off ridge situation. The general mineral paragenesis of the dykes is: plagioclase (An_{40-70}), albite, hornblende, actinote, ouralite, epidote, chlorite, zeolites, sphene and opaque minerals.

Pillow lavas and volcano-sedimentary rocks

The final members of the Hatay ophiolite are the pillow lavas and a volcano-sedimentary series. The outcrops of pillow lavas are NE of the Kızıl Dağ near the villages of Kömüçukuru, Yapraklı Yayla, Tahtaköprü, Üçoluk and Deliler Mahallesi. A direct contact between the sheeted complex and the pillows is not visible. However, in several places in the lower parts of the pillow lavas, diabase dykes with chilled edges are seen which were probably the feeders for the upper levels of the pillows. The contacts with the other members of the ophiolite are tectonic.

Near Tahtaköprü, the pillows are overlain discordantly by Maestrichtian sediments (Çoğulu, 1975).

A very interesting section can be described near Yapraklı Yayla. Pillowed and spilitic massive lavas are overlain by iron bearing diabasic breccias and micro-conglomerates bearing reworked rudistes of Upper Campanian to Maestrichtian age. Above the conglomerate the sedimentary facies is deeper.

The dismembered pillow-lava sequence shows first aphiric tholeiites then olivine tholeiites. The same order of extrusion is described in the Semail ophiolite of Oman (Laurent et al., 1980).

The pillow lavas from Habib Neccar Dağı (Mt. Silpius from Dubertret) have a quite different look. They are described by Dubertret (1955) as "sakalavite" and are associated with olivine tholeiitic lavas and Mn-bearing sediments. These rocks, in which the order of mineral crystallization resembles that of the cumulate gabbros and ultramafics, are of particular interest, for they provide evidence for a very rapid cooling of a magnesium rich magma (Laurent et al., 1980).

Selçuk (1981) has described the volcano-sedimentary sequence, near Yayladağ and between Harbiye and Antakya, as being made up of radiolarites, clayey limestones, sandstones and pillow lavas (sakalavites), which are in tectonic contact with the other members of the ophiolite. The age would seem to be Upper Campanian. This unit is strongly different from the Syrian (Baër-Bassit) volcano-sedimentary sequence. The later was described by Parrot (1977). It has been dated from Triassic to Turonian. At the base, the volcanic elements have a tholeiitic character. It changes then to alkaline and strongly alkaline at the end. Tectonically, the volcano-sedimentary sequence have been thrust with the ultramafites. The difference in age between Hatay and Baër-Bassit volcano-sediments could be explained, as proposed by Selçuk, by the more internal position of the Baër-Bassit, hence the evolution in age of deposition from South to North. It is also possible that the sequences are genetically different according to part of their volcanism but also in their structural positions.

It should be added that the ophiolite assemblage near Mertavan (some 80 km NE of Antakya) has a greater similarity to that of the Baër-Bassit ophiolite than to that of the Kızıl Dağ.

Mineralogical transformations in ophiolitic rocks

The Hatay ophiolite exhibits three principal transformations: serpentinisation, the more or less complete formation of rodingites and the development of a weak metamorphism (ocean floor type).

The ultrabasic rocks of the Kızıl Dağ massif, either tectonites or cumulates, show different degrees of serpentinization. The olivine transforms into lizardite and chrysotile, the pyroxenes into bastite and chlorite.

In the weakly tectonized zones, the serpentinization is developed in a closed system with an increase in volume: in the highly tectonized zones the system was an open one and the serpentinization was at constant volume (Coleman, 1971). The diagram MgO/SiO_2 as a function of H_2O can give some indications as to the state of the system; for if a large variation in the ratio MgO/SiO_2 is observed the system in which the serpentinization occurred would have been an open one without an increase in volume. The ratios MgO/SiO_2 calculated from the chemical analysis data of Çoğulu et al. (1975) indicate a remarkable constancy. From similar results obtained by Parrot (1973; 1977) for the Hatay and the Baër-Bassit the latter author proposes that the serpentinization took place before the emplacement of the peridotites in these massifs, that is already at the oceanic ridge. It is largely accepted that the serpentinization also influences the intrusive rocks associated with the ultrabasics and therefore allows the more or less complete formation of rodingites and/or of ophispherites.

In the Kızıl Dağ the first phenomenon is seen in the basal cumulates and in the intrusive along the coast and at Karaçay.

In the basal cumulates, particularly the plagioclase ultrabasites the plagioclases are often partially transformed into hydrogarnets.

The development of vesuvianite, prehnite, zoïsite, chlorite, sphene, Mn-diopside, pumpellyite, tremolite and calcite, beside the relics of the mafic minerals and of the plagioclases (Çoğulu, 1980) is also observed.

The transformation into rodingites does not affect all the intrusive rocks in the serpentinites of the Kızıl Dağ. Moreover, the degree of transformation is not the same in all the dykes. The rodingites of the Kızıl Dağ come from the gabbro-pegmatite dykes, the leuco-gabbro dykes and the diabase dykes.

The ocean floor metamorphism, at the limit of greenschist and zeolite facies is weaker than that of the Troodos (Smewing, 1975). It affects part of the gabbros, the entire sheeted complex and very probably the pillow lavas.

Geochemistry, geochronology and palaeomagnetism

Major element analyses of the tectonites, the cumulates and the sheeted complex when plotted in a FMA diagram group into three zones. The progressive enrichment in iron oxides reaches a maximum in the sheeted complex which is also enriched in alkali elements (Çoğulu et al., 1975; Laurent et al., 1980).

Studies of the concentrations of rare earth elements in the pillow lavas, in the diabase dykes (unpublished data) and in the gabbros (Delaloye et al., 1979) show the same trends with a depletion in the light rare earths. The pillow lavas have the highest concentrations of rare earths. Such a distribution indicates that these rocks were derived in a ridge zone, from an asthenosphere uniformly depleted in rare earths (Delaloye et al., 1980a). In their comparison of tholeiites from island arcs with those from oceanic crust Beccaluva et al. (1979) have proposed that the Ti/Cr versus Ni diagram enables to distinguish between these two types. The use of this diagram here, does not give evidence in favour of an island arc origin for the Hatay ophiolite (Delaloye et al., 1980a).

A study based on the trace element analysis of the Hatay and Baër-Bassit lavas leads to suppose that they are closer to basalts from volcanic arc or to basalts from a marginal basin. The absence of andesites suggests that neither of the two massifs belongs to a typical island arc. For this reason, a marginal basin origin remains the most likely (Delaloye and Wagner, 1984).

Similarly small marginal basins have been proposed from Greece to Oman (Robertson, 1977) as the origin of many ophiolitic massifs, particularly like Troodos (Gass, 1979).

The geochronological ages determined by the potassium - argon method can be interpreted in different ways: either as a cooling age whilst part of the ocean floor, or as the age of a metamorphic event more or less contemporaneous with their tectonic emplacement on the continental margin (Delaloye et al., 1980b). The results from the pillow lavas should be treated with some care as these rocks are strongly altered. The crystallization age of these rocks has an upper limit set by the Maestrichtian transgression on the pillow lavas (Delaloye et al., 1980b).

The geochronometrically determined ages of the Hatay sheeted complex lie between 73 and 99 million years indicating a Middle Cretaceous or slightly older age. The ages obtained from the green amphiboles extracted from the gabbros are slightly greater: Late Jurassic.

The amphiboles from the metamorphic basement of the Baër-Bassit ophiolite give an age of 85-95 Ma. As this basement was produced by a detachment and spalling of the oceanic crust (Coleman, 1981) and the ridge axis is a zone of weakness for such a detachment the part of the ophiolite associated with these amphibolites would represent the youngest part of the lithosphere. Thus the isotopic age obtained for such an environment would be the upper limit for the age of formation of the ophiolite. It is therefore possible that the Hatay and Baër-Bassit ophiolites represent the youngest parts of a ridge which was already active during Jurassic times (Delaloye and Wagner, 1984).

The magnetic properties of the ophiolite sequence are similar to those of the neighbouring Troodos massif (Çoğulu et al., 1975). With regard to the interpretation of the source of marine magnetic lineations, these properties confirm that the dominant remanent magnetization lies in the pillow lavas.

The contribution of the sheeted complex is weak whilst that of the gabbros is not negligible and could play a secondary role. The other deeper members of the ophiolite do not contribute as they were situated below the Curie point isotherm. However, if an intra oceanic tectonic regime was present which favoured the uprise of a serpentinized peridotite, these inferior members could also constitute an intensely magnetized source.

As far as the palaeomagnetism, in the true sense of the term, is concerned only the sheeted complex and the gabbros, after a thermal or alternating field demagnetization, show a stable characteristic remanent magnetization. However, due to the difficulty of defining a reliable palaeo-horizon in order to apply the necessary geological corrections, the analysis of the directions is somewhat delicate. Our directions are coherent on the scale of the tectonic blocks which make up the ophiolite massif and they indicate tilting and rotation about a vertical axis. Thus it is difficult to calculate a satisfactory palaeopole. The gabbros indicate a palaeolatitude of 10°N (of the palaeo-equator) which is compatible with the palaeo-reconstructions for this period (Irving, 1977).

The absence of reversed rocks in the ophiolite, as well as the age of the ophiolite indicates a period of normal polarity.

Effusive rocks

In the Hatay province and in northwestern Syria, the volcanism which is not directly related to the ophiolites was produced during three principal phases: Triassic, Jurassic and Neogene-Quaternary. The volcano-sedimentary sequence of the Baër-Bassit, of Triassic age includes flows, often in the form of pillow lavas, of tholeiite composition (with a slight alkaline tendency) (Parrot, 1974; 1977). This volcanism is interpreted by the author as evidence of a phase of rifting affecting the northern border of the Afro-Arabian platform.

The alkaline extrusives of Jurassic age produced by an intraplate volcanism have been described by Parrot (1977) at Baër-Bassit and form a basanite-lamprophyric ensemble and a phonolite tingaitic ensemble.

The Neogene-Quaternary volcanism of fissural activity is well developed in the Hatay. In this province the intra-Miocene and Quaternary basalts are particularly abundant in the Karasu valley. It is in this fault zone that the Dead Sea Rift meets the East Anatolian transform fault, produced by the collision during the Miocene of the Arabian platform with the Taurus-Anatolia platform. Çapan and Tekeli (1983) have shown that the valley was filled during the Quaternary by "aa" and "pahoe-hoe" fissure flows.

Olivine basalts are the most frequent in the seven different flows. The same authors note the presence of olivine and quartz tholeiites with a few alkali olivine basalts. Amongst these basalts, the olivine tholeliites with normative olivine and hypersthene are the most abundant and cover a large area along the axis of the valley. On the contrary the alkaline olivine basalts and the quartz tholeiites are less frequently met and tend to be found along the western boder of the valley. It is probable that these two rocks were produced from two different magmas: alkali olivine basalt and tholeiite. Chronologically, the alkali olivine basalt is the younger; the olivine tholeiite is the oldest.

COVER FORMATIONS

The ophiolite sequence and the basement rocks are covered transgressively by sedimentary terrains whose total thickness is estimated at some 3000 metres. The timing of the transgression is from Upper Cretaceous to Miocene. The Upper Cretaceous cover is illustrated in Fig. 3.

Upper Cretaceous

The oldest of the transgressive formations which cover the ophiolite are of Upper Maestrichtian age. They are conglomerates with ophiolitic components, sandstones, limestones, marly limestones and marls. Several species of *Hippurites* are present, *Orbitoides*, *Siderolites* , *Loftusia* and *Globotruncana* (*G. mayaroensis*, *G. arca* and *G. gansseri*) (Selçuk, 1981).

Palaeogene

The Upper Maestrichtian is overlain concordantly by a series of clays, sandstones, limestones, marly limestones, cherty limestones and marls whose age is from ?Palaeocene to Upper Eocene. The total thickness amounts to some 600 metres. The microfauna is equally rich in planctonic species (*Globorotalia*, *Globigerina* , *Globigerapsis*) and in benthic species (*Nummulites*, *Discocyclinae* , various Rotaliidae, Alveolines, *Orbitolites* , various Miliolidae and *Dentalium*) (Selçuk, 1981).

Neogene

The Miocene is always transgressive on the previously mentioned units, the autochthonous, the ophiolite or even the neo-autochthonous. The Lower Miocene is missing and the total thickness is of the order of 1600 metres. The depositional environment is shallow to very shallow, but occasionally passing laterally to pelagic sediments. The sediments are made up of conglomerates, sandstones, reef limestones, clays, marls and marly limestones, very rich in macro- and micro-fauna:
Echinoidea: *Clypeaster*, *Echinolampas*, *Schizaster*, *Psammechinus*;
Bryozoa: *Tarbellastraea*;
Bivalvia: *Pycnodonta*, *Chlamis*, *Ostraea*, *Pecten*;
Benthic foraminfera: *Borelis* , *Operculina* , *Heterostegina* , Rotaliidae, Nodosariacea with many Robulus, Textulariidae, *Amphistegina* , milioles;
Planktonic foraminifera: *Orbulina*, *Globigerinoides* , *Globorotalia* in particular, *G.* cf. *archeomenardii*, *Globoquadrina*;
Ostracoda: various (Selçuk, 1981).

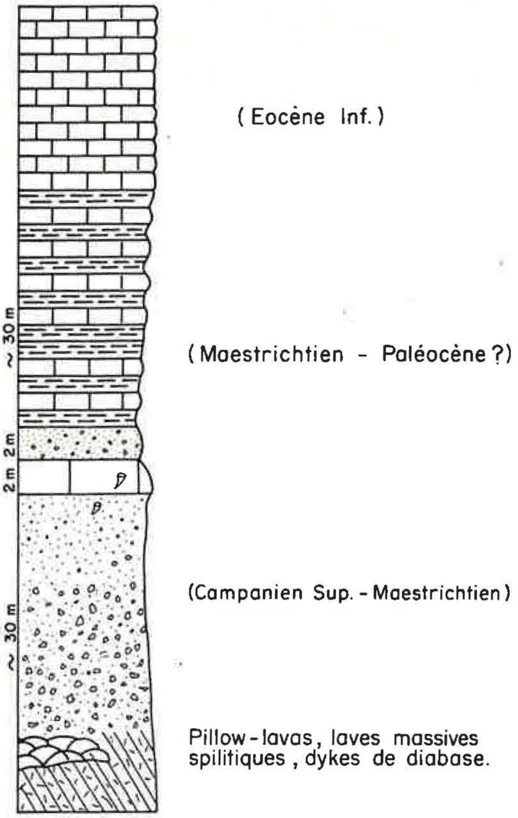

Fig. 3 - Detailed section near Yaprakli Yayla showing the sedimentary cover of the ophiolite.

The transgressive Pliocene consists of sandstones, marly limestones, clays and slaty clays; its thickness varies between 100 to 400 metres. It is rich in fauna: Gasteropoda: *Turritella*, numerous *Cerithium*, *Strombus*, *Natica*, *Narsa*, *Conus*; Bivalvia: *Ostraea*, *Lucina*, *Cardium*, *Pitaria*, *Venus* and *Dentalium* (Selçuk, 1981).

Quaternary

The Quaternary is represented by a conglomerate with angular or rounded poorly cemented fragments, travertines, erratics, alluvium and beach sand.

PRINCIPAL FEATURES OF THE TECTONICS AND THE PALAEOGEOGRAPHY

The Amanos mountain chain is in the form of a mega-anticline running NE to SW with its Lower Palaeozoic core, situated in its northern part. The strikes of the different terrains forming this anticline are generally NE-SW and the dips are either to the NW or more steeply to the SE. In general the degree of folding and the tectonics decrease from north to south.

The major faults are oriented NE-SW and are parallel to the Karasu graben. Due to transverse faults the axis of the anticline has a more or less sigmoidal form. In its northern part the facies associated with the Lower Palaeozoic formations indicates a terrestrial coastal or neritic sedimentation. There is an important unconformity between the Lower Palaeozoic and the comprehensive series of the Late Palaeozoic and Lower Mesozoic (Janetzko, 1972). Fragments of petrified woods found at the base of the Late Palaeozoic as well as the red colour of the Palaeozoic quartzitic slates are evidence for an uplift at the end of the Acadian (Atan, 1969; Janetzko, 1972). Foraminifera indicate for the presence of Triassic, Upper Jurassic, and Upper Cretaceous. A sedimentation in a shallow environment on a continental margin is evidenced by the bituminous limestone facies, by the presence of anhydrite at several levels, by reef limestones in a comprehensive ancient series, by a bauxite horizon in the Cretaceous and by the appearance of Ostrea in the Upper Cretaceous.

As a consequence of orogenic movements during the Senonian, the ophiolites were overthrust onto the platform.

The history of the emplacement of these ophiolites can be divided into two episodes. The first directly concerns the emplacement, the second the post emplacement tectonics.

In the northern part of the Kızıl Dağ massif, near the village of Kömürçukuru, in a small tectonic window, the ultramafites rest tectonically in contact with the Albian-Aptian limestones. This contact has been interpreted as the thrust plane of the ophiolites (Dubertret, 1955; Aslaner, 1973).

Near this contact, lenses of limestones, 20-40 m long and 10-20 m thick are interleaved in the ultrabasites. Most of these blocks are Lower or Upper Cretaceous in age but the youngest is Campanian whilst the oldest is probably Triassic. The lithology of the limestones is similar to that of the carbonates of the neighbouring area in Syria (Al-Maleh, 1976). Therefore these limestone lenses have originally been part of carbonate sequences from the Arabian continental platform which were detached and incorporated in the sole of the ultramafites during the emplacement of the ophiolites. However, the limestone beneath the ultrabasite may itself be a large tectonic unit. Making this point, the age of emplacement of the ophiolites could be considered as post Campanian/Pre-Maestrichtian to Maestrichtian.

The sense of overthrusting can be deduced from studies in the neighbouring regions (Delaune-Mayere et al., 1976; Parrot, 1973; Parrot and Whitechurch, 1978; Ricou, 1971); this movement would be NW-SE.

From the radiometric age of the amphibolitic sole of the Baër-Bassit, 20 to 25 million years went by between the initial detachment (pre-Campanian) and the emplacement of the ophiolites in their actual position (Delaloye and Wagner, 1984).

The post emplacement evolution of the ophiolites in the Hatay province took place in several stages (Tinkler et al., 1981; Selçuk, 1981) of which the following are the most important:

- formation of Maestrichtian conglomerates with ophiolitic fragments,
- normal post-Maestrichtian - pre-Lutetian faulting
- normal post-Maestrichtian - pre-Miocene faulting
- post Miocene structures post Pliocene and recent structures.

The Maestrichtian conglomerates with ophiolite fragments do not seem to have undergone a substantial displacement. They were probably formed by erosion along scarp faults which occurred in the uppermost parts of the ophiolite suite.

Near Harbiye the presence of a normal fault in the Lower and Middle Cretaceous sediments but covered by Lutetian limestones indicates that a faulting tectonics was active during pre-Lutetian times and that this tectonic regime was not limited to the ophiolite body.

At the interior of the ophiolite massif the contacts between the different members are normal faults. These faults oriented NNE-SSW, are responsible for the uplift of 1000-2000 metres of the central part of the Kızıl Dağ massif. Sealed by Miocene sediments these faults are pre-Miocene. Like the Maestrichtian, the Miocene also encloses a conglomerate formed of ophiolite and limestone fragments. Near Uçoluk, the pillow lavas are tilted 60° to the SE and are covered by Maestrichtian and Palaeocene sediments which dip only 40° towards the SE. The latter are overlain by Miocene sediments dipping 20° to the SE.

These observations allow to define the sequence of events:

1) Tilting of the pillow lava sequence;
2) Unconformal deposition of Maestrichtian and Palaeocene sediments;
3) Tilting of Maestrichtian and Palaeocene sediments;
4) Sedimentation with unconformity of Lutetian on the Palaeocene;
5) Tilting and erosion of the Lutetian;
6) Deposition of Miocene with unconformity of the Miocene on the Palaeocene;
7) Tilting of the Miocene (Tinkler et al., 1981).

Thus at least two, probably three tilting episodes of the block can be postulated. Although there is no formal evidence, the Miocene conglomerate would appear to have been produced by erosion along a fault escarpment.

The post Miocene structures which are a regional phenomenon are well observed in the tilting of the sediments. The normal faults described by Dubertret (1955) in the Karasu valley are post Pliocene structures. Along the sea coast north of Şahanlikkayası Burnu two beach terraces uplifted by 50 and 75 metres are evidence of recent structural episodes.

MINERAL RESOURCES

The economic potential of the Amanos mountain range consists of chromite, iron, iron-bauxite, asbestos, manganese mineralizations and possible nickel and cobalt.

The chromite occurs as many small pods scattered in the ultrabasics either as schlieren or leopard skin. The direction of the primary magmatic contact between the chromite and the host rock is approximately E-W with a dip of 40° to 50° to the South (Aslaner, 1973).

The iron mineralization which could be of some economic importance is in the Albian-Cenomanian limestones and the Triassic limestones (Atan, 1969). Iron is also found in association with manganese in the diabases but is not of any economic importance.

The ferriferous bauxite is found in two horizons of Albian-Cenomanian and of Triassic age.

The asbestos is present in the ultramafics as veins up to 10 cm in thickness.

The serpentinites and the chromitites contain localized concentrations of Ni and Co which could be of some interest.

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