THE OPHIOLITIC SERIES OF TURKEY*

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ABSTRACT. — The Anatolian ophiolitic series consist mainly of harzburgites, dunites, diabases and gabbros being frequently serpentinized, sericitized or chloritized. They are associated with radiolarites, slates, dark flysh-like deposits and various limestone types. The whole generally form intensively disturbed masses including «exotic» carbonate blocks of various age and size. Limited occurrences of Paleozoic rocks excepted, the Anatolian green rocks are of Lower Mesozoic age, as it is shown by their stratigraphic position. But the textural unstable ophiolites were disrupted during the Middle-Upper Cretaceous paroxysm, by both thrusts and submarine slides, which explains why they were frequently unconformly overlain by or intercalated with Upper Cretaceous sediments. The main green rock zones of N and S Anatolia show a striking parallelism to the major earthquake zones of the country. Both phenomena must be related evidently to important, deep-seated longitudinal tectonic dislocations (like boundaries between deep-seated tectonic units — f. ex. between foreland and orogenic zone — or deep root zones of nappes).

The ophiolitic series of Turkey (Serpentine Series, Green Rock Series) consisting of ultrabasic extrusive rocks and associated sediments are a characteristic element of the Alpine folds of the country. Representing a typical geosynclinal formation, these rock successions are strongly related to the development of the Alpine orogenic belt; their particularities furnish information on the deep mechanics of the Alpine orogeny.

The chromite and magnesite ore deposits of Turkey are related to the ultrabasic «green rocks»; the famous sepiolite («meerschauni») found in old alluvial deposits on the N border of the Eskişehir basin is evidently a special decomposition product of these rocks (hydrothermal effects originating in the fault zone along which these deposits are developed). Following some authors (f. ex. Ami, 1941), the bauxite layers interstratified in Upper Cretaceous carbonates in the Central Toros Mountains (S Anatolian Folds) could be resedimented decomposition material derived from weathered green rocks. Iron ore deposits developed in the ophiolite areas in SE Anatolia and the Aegean region seem to be of a similar origin (İlhan, verbal information).

COMPOSITION AND ORIGIN OF THE OPHIOLITIC SERIES

The green rock series include magmatic extrusive rocks and a characteristic sequence of associated sediments. The *magmatic range* is represented by harzburgite, dunite, melaphyre, spilite, diabase, gabbro and diorite. Pillow lavis and agglomerates are reported from some localities. Several of these rock types are frequently found in the same green rock mass, where they are linked together by horizontal and vertical passages. As result of tectonic pressure, these rocks are generally more, or less serpentinized, chloritized, sericitized or schistous.

The *associated sediments* consist of generally dark or green-colored flysch-like sediments; radiolarites; mostly thin bedded, reddish, pirrk or dark-colored limestones with silica nodules.

«Exotic blocks» are frequent in these successions of rocks and sediments; the blocks include plutonic or metamorphic material, but generally carbonates, the age of which varies from Paleozoic to Cretaceous. Their size is in the limits of several m^3 and several hundred m^3. All these rocks generally form intensively mixed and disturbed «melanges». In SE Anatolia (Malatya, Van, Hakkari regions) this melange shows a distinct dynamometamorphism of epi-grade comparable to that of the «Grisonides» nappes of the E Alps.

On the contacts, the more plastic serpentinized ultrabasic material is pressed into the fissures of the harder carbonates simulating magmatic contacts; but true magmatic contacts are reported only from a few isolated cases.

The observations made in Turkey seem to confirm more or less the ideas about origin and formation of the ophiolitic series forwarded by the geologists in the Dinarides branch of the orogenic belt, in Yugoslavia, Albania and Greece (Aubouin, Brunn, Dubertret, etc.); the magmatic component is initial magma in form of submarine extrusive flows apparently originating in response to important tectonic events within the eugeosyncline (see, f. ex., Aubouin, 1965). The radiolarites and other siliceous sediments were formed during and after the ultrabasic eruptions.

THE AGE OF THE OPHIOUTIC SERIES

The ophiolitic series were displaced by tectonic movements (thrusts and submarine slides) after their formation; they form complicated tectonic mixtures with sediments of various age, but normal stratigraphic contacts with sediments of well-defined age can rarely be observed. On the other hand, «normal» basalt flows and dykes accompanied by agglomerates and pillow lavas produced during continental extrusions, but never associated to the typical sediments of the «green rock series», were sometimes confounded with the ultrabasic series. Such eruptions occurred locally during the Triassic, Jurassic and on a large scale in the Upper Cretaceous (Arni, Brunn, Erol, Geol. Map 1:500,000 of Turkey). These rocks cut sometimes the green series and their contacts with Upper Cretaceous sediments were therefore erroneously considered as magmatic contacts of the green rocks themselves (f. ex. Hekimhan region in SE Anatolia). Farther, two events must be separately taken in consideration:

1. The age of the submarine extrusions of the ultrabasic rocks and the formation of the associated sediments;

2. The age of the emplacement of these materials in their actual stratigraphic and tectonic position as a result of various orogenic movements.

Because of all these complications, it was and still is not easy to establish the exact age of the Turkish ophiolitic series. Very contradictory opinions were and still are forwarded about this subject. Age estimation varies between Precambrian (Peyve), Paleozoic (Hiessleitner), Lower Mesozoic (Erol, Arni, İlhan) and Upper Cretaceous-Eocene (f. ex. Geol. Map of Turkey). Following the latter, Paleozoic green rocks are developed only in a few limited localities where they are associated to various Paleozoic series (Konya, Bolu, Edremit, Yenice and Yusufeli regions). As the ophiolitic series are the product of tectonic events in geosynclinal areas and as remains of the Hercynian orogeny included in the Turkish Alpine Folds show that the Hercynian belt extended through Turkey, formation and existence of Paleozoic ultrabasic rocks can theoretically be expected in the country. «Green Schists» included in metamorphic series in the N and S Anatolian Folds may be metamorphosed remains of Paleozoic ultrabasic rocks.

All the other ophiolitic rocks of Turkey are today considered as post-Paleozoic and belonging to the Alpine orogeny. This is proved or shown as very probable by many observations. F. ex. in the N of Erzincan (N Anatolian Folds), in the NE of Cihanbeyli (Central Anatolian Folds), in the Kangal and Pınarbaşı areas (S Anatolian Folds) the green rock succession is unconformably overlain by the widespread Upper Jurassic-Lower Cretaceous carbonate series. In all these localities, the superficial levels of the ophiolitic series are deeply weathered and altered (they must have been exposed to atmospheric agents before having been buried again) and the sandy basal beds of the overlying carbonates contain angular pieces of green material (İlhan).

The carbonates under- and overlying the green rocks in the *Elma Dağı* region (E of Ankara, branch of the N Anatolian Folds) are considered as partially Triassic by Erol and as mostly Jurassic by Ketin. Fossiliferous Liassic and clastic Middle Jurassic cover the ophiolites in the N of Ankara and in the Amasya region, respectively (N Anatolian Folds, Arni). Jurassic, in some cases Upper Triassic age of the green rocks were recently reported by Brunn and his collaborators from the central sectors of the S Anatolian Folds (N of Antalya) and Arni considered as probably Upper Jurassic-Lower Cretaceous the green rocks of the Akseki-Seydişehir region of the same folds.

On the other hand, the ophiolitic series are very frequently intercalated in or overlain by Upper Cretaceous sediments in the N Anatolian, S Anatolian and Aegean Folds; f. ex.: Geyve, Sarıköy, Çerkeş, Çankırı, Tokat, Tozanlı, Tortum-Oltu in N Anatolia; Antalya-Belkis, Beyşehir, Pozantı, Hekimhan, Malatya, Arapkir, Van in S Anatolia; Emet and Bornova in the Aegean region. Clear unconformities can separate the sometimes deeply altered green series from the overlying Cenomanian, Turonian or Maestrichtian carbonates or flysch deposits with colored conglomerates and Rudist-reefs; but sometimes the green series seem to be simply interstratified between the Upper Cretaceous deposits.

This frequent association of the ophiolitic series with Upper Cretaceous strata may have been the reason for which the green rocks are considered by many geologists as contemporaneous with these strata (see Geol. Map of Turkey 1:500,000 and Explanatory Notes).

In relation to the age problem of- the Turkish green rocks, the situation developed in the Hatay area (E of the Gulf of İskenderun, near Yayladağ, in the Turkish-Syrian border zone) merits a special discussion. Here, the ultrabasic rocks are intercalated between fossiliferous Campanian sediments of shelf character. Following Dubertret (1954), the dioritic mass of Kızıldağ (NW of Yayladağ) was the eruption center of the ultrabasic rocks and he gave a detailed description of the gradual passage of the diorites into the harzburgites, etc. This author, therefore, considers the green rocks of the Yayladağ area as *in situ* and extruded during the Upper Cretaceous. As a continuous green rock zone extends from Hatay along the southern external border of the Alpine folds until the Iraquian territory, this entire zone should be Upper Cretaceous. Though the interpretation given by Dubertret seems to be satisfying at the first look, some recent observations suggest a quite more complicated stratigraphic and tectonic pattern: in the direct northward extension of the Kızıldağ-Yayladağ area, completely tectonized, disturbed and «squeezed out» green rocks form a thin layer (several centimeters to several meters thick) between a «comprehensive» carbonate series beginning with Triassic or Jurassic levels and the underlying Paleozoic succession (İlhan, verbal information). Here, the green rocks cannot be simply *in situ,* but they must have formed the base (lubricant) for an important horizontal thrust movement. The sections illustrating this situation are along forest roads constructed in the last years; in the times of Dubertret it would have been impossible to make such observations in this mountain range being densely covered with forests.

Recently, an other objection against ah Upper Cretaceous age of the Hatay green rocks was expressed by Peyve. Based on observations made in the Yayladağ area and in Syria, this author insisted on two facts:

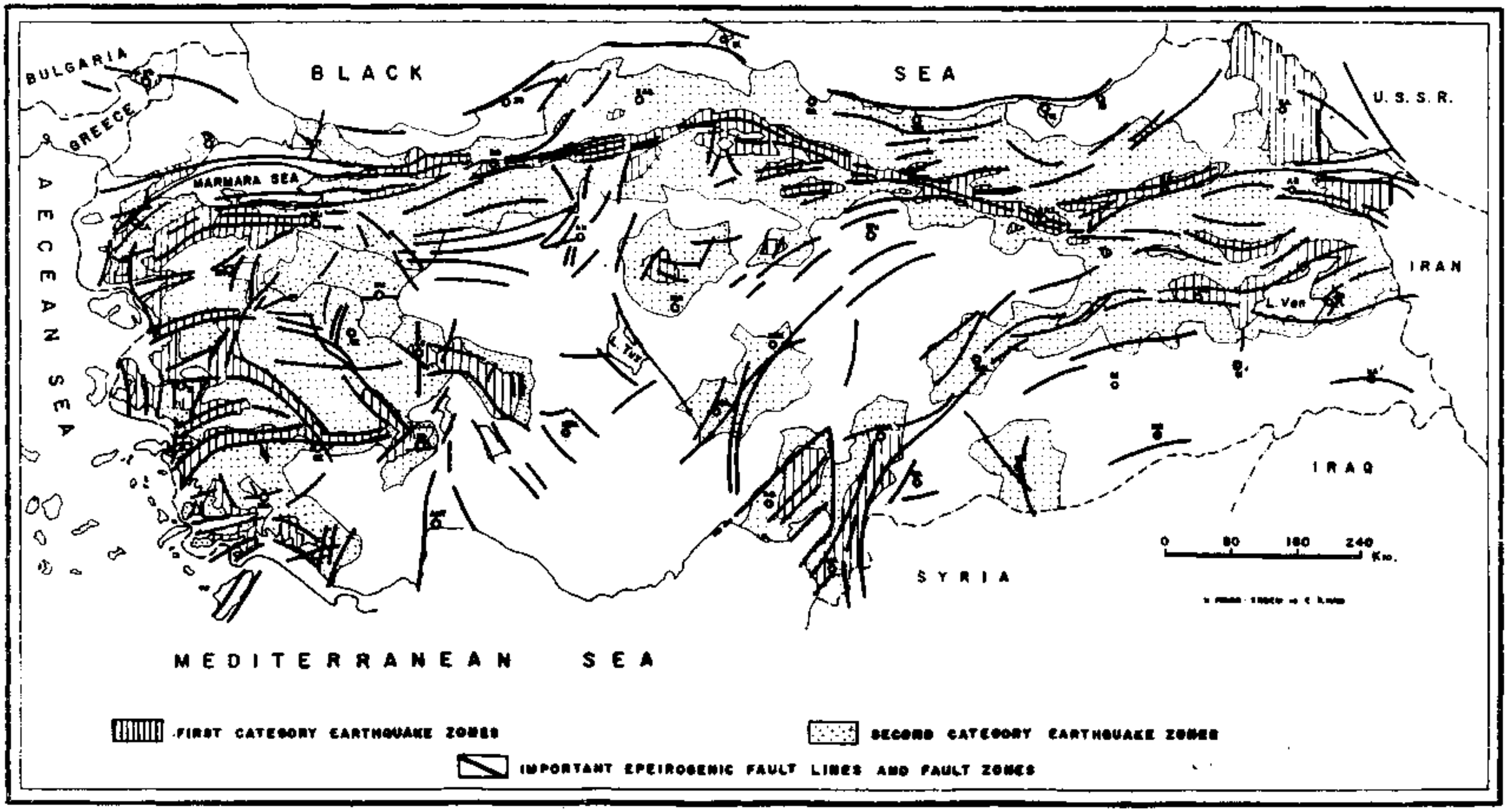

Fig. 1 - Seismic zones and epeirogenic fault patterns in Turkey (after N. Pınar & E. İlhan, 1952; E. İlhan, 1971).

Localities shown on the map : Ad - Adana, Af - Afyonkarahisar, Ağ - Ağrı, An - Ankara, Ant - Antalya, Ba - Balıkesir, Bo - Bolu, Bu - Bursa, Çk - Çanakkale, De - Denizli, Di - Diyarbakır, Ed - Edirne, Erz - Erzincan, Er - Erzurum, Es - Eskişehir, Ga - Gaziantep, Ha - Hatay, Ha' - Hakkâri, İsp - İsparta, İst - İstanbul, İz - İzmir, Ka - Kars, Kas - Kastamonu, Kay - Kayseri, Kır - Kırşehir, Ko - Konya, Kü - Kütahya, Mal - Malatya, Ma - Maraş, Mş - Muş, Mu - Muğla, Niğ - Niğde, Or - Ordu, Ri - Rize, Sa - Samsun, Si - Sinop, Si' - Siirt, Siv - Sivas, Te - Tekirdağ, Tr - Trabzon, Ur - Urfa, Va - Van, Zo - Zonguldak.

1. Ultrabasic rocks are related to the geosynclines; but the deposits under- and overlying the green rocks at Yayladağ show the shelf facies of the foredeep. (As a matter of fact, this region belongs to the external border of the Alpine folds and the Alpine belt; it may represent miogeosynclinal, but never eugeosynclinal environment.)

2. The development of the ophiolitic series could not have been possible in such a short time, as it is represented by the Campanian-Maestrichtian.

So, Peyve concluded, that the green rocks of the Yayladağ region must be of older origin and have been transported into their actual position between Maestrichtian strata by tectonic movements. It may be interesting to note that the position of the green rocks in and on chalky Upper Cretaceous beds between Maraş and Gaziantep, in the NE extension ot the Hatay green rock area, was explained already in 1912 by Kober, by thrusting from the S Anatolian Folds toward the fore-deep. So, the famous section of Yayladağ no longer can be considered as an absolute proof of the Upper Cretaceous age of the green rocks situated on the external border of the S Anatolian Folds.

The existing data shortly mentioned above can be interpreted in two ways:

1. Ultrabasic extrusions occurred at several times, namely before the deposition of the Upper Jurassic-Lower Cretaceous carbonate series and, later on, during the Upper Cretaceous. This would explain why ultrabasic rocks are covered, in some regions by U. Jurassic beds, while in other places intercalated in or overlain by U. Cretaceous sediments. As the development of the orogenic movement progressed from the axial zone of the geosynclinal trough towards its external borders, the green rock extrusions could have occurred (theoretically) earlier in the inner and later on in the external sectors of the belt. But, if the ultrabasic extrusions are related to the eugeosynclinal phase of the orogenic belt (in the sense of Aubouin), such repeated extrusions should be excluded: eugeosynclinal conditions existed, in the Turkish sector of the Alpine orogenic belt, in the Lower Mesozoic only and not in the Upper Cretaceous (which is represented by shallow water conditions-shallow water carbonates and littoral deposits, like elastics and reefs). If, on the other hand, the ultrabasic extrusions are related to the displacement of plates, then the repetition of the arrival of green rocks could be possible also in the miogeosynclinal phase (Cretaceous); provided that the repeated movements of plates during the Mesozoic can be proved.

Aubouin (1965), who considers the Alpine ophiolitesas being of mostly Upper Jurassic age, suggested that the green rocks found in the external zone of the S Anatolian Folds and supposed to be Upper Cretaceous, could perhaps represent a marginal development of the intracratonic fissure eruptions known from the Cretaceous of the cratogenic areas extending south ofthe orogenic belt. These eruptions produced the basalt sheets characteristic of this part of the Alpine foreland (Arabian and Indian Blocks); distant extremities of some of these sheets could have reached the sea along the southern shore of the Alpine geosyncline. The fact, that the ophiolites of supposed U. Cretaceous age in question are developed in the area where the S-N directed big fracture zone of the Dead Sea - Syrian graben intersects the external border zone of the Alpine belt, seems to confirm Aubouin's interpretation. But, on the other hand, the next Cretaceous basalts (to the area in'question) are known from Lebanon; no basalts of this age'are reported from the border sections of the Arabian shield in SE Ahatolia, where only Upper Tertiary basalts exist.

2. The ultrabasic eruptions took place in the Lower Mesozoic (as it was the case in the Dinarides and Carpathides sectors of Alpine belt, too), but most of these rocks, together with their associated sediments, were displaced during tectonic disturbances which succeeded the extrusions, for instance during the Upper Cretaceous paroxysm (and during the deposition of the U. Cretaceous

sediments), by both submarine slides and real thrusting. This explains why the green rocks are frequently overlain by or intercalated in U. Cretaceous sedimentary sequences. Klemm, for example, mentions that «material originally derived from Upper Jurassic intrusions was deposited in a chaotic serpentine - red bed sequence in Upper Cretaceous marls» (by submarine slides).

The horizontal transport was repeated, on a reduced scale, during the Upper Miocene paroxysm on the southern external border of the Alpine belt: an important mass of green rocks is situated as «olistostrome» in the Upper Miocene strata in the Başur Valley west of Siirt (SE Anatolia, Alpine thrust front).

Serpentinized and chloritized green rocks are texturally unstable and easily affected by weathering and erosional agents. So, they are an excellent «lubricant» for moving masses and form efficacious slide and thrust planes; this occurs even today: landslides are frequent in the green rock areas.

TECTONICS OF THE GREEN ROCK SERIES IN ANATOLIA

It was mentioned before that serpentinized and chloritized, therefore texturally unstable ultrabasic rocks act as «lubricant» for tectonic movements. So, it is not surprising that ophiolitic series form very often thrust nappes or the base of such nappes. The best examples of such phenomena are the 700 km long thrust front of the S Anatolian Folds in SE Anatolia (its total length is several thousand km, together with its SE ward extension through Iraq and S Iran, until the Oman Ranges); the thrust nappes in the «Lake Region» of the Central Toros Mts. (Akseki, Beyşehir, Eğridir, Isparta, Antalya and Elmalı regions); the thrusts in the Ankara, Erzincan, Erzurum (N Anatolian Folds), İzmir and Akhisar regions (Aegean Folds).

Many observations illustrate the intensity of the tectonic movements to which the ophiolitic series were exposed: in some areas green rocks and associated sediments, together with various other sedimentary series, form complicated tectonic mixtures and «giant breccias» (expression used by the Carpathian geologists), like the «Ankara melange» (McCallien, Erol) and the «Van-Hakkari complex» (Türkunal, Geol. Map of Turkey 1:500,000). In the regions of İzmir, Manisa, Akhisar (Ami; İlhan, 1954), Malatya, Pütürge, Van and Hakkari (İlhan, 1954, 1971), the green rocks and associated sediments show regional dynamometamorphism of epi-grade. So, the ophiolitic series of these regions were (and partially still are) sometimes mapped as «Paleozoic slates» or «Crystalline».

Some scientists (f. ex. Rigo and Kuendig) are inclined to explain exclusively by submarine slides all the tectonic displacements into which ophiolitic series are implicated. Such an explanation may be possible for relatively limited areas, like the «melange» of the Elma Dağı region (E of Ankara, Erol; Norman). But it seems impossible to explain in this way disturbed and dislocated zones extending over several hundred km or the regional dynamometamorphism affecting surfaces of several hundred km^2. Such phenomena must be due to real thrusting movements of Alpine dimensions.

Very probably, both types of movements may be responsible for the displacement of green rock series. For instance, on the front of progressing nappes, slides may have occurred frequently and olistostromes formed in this way. Nice examples of such slides, detached from advancing nappes at their front and buried below the progressing thrust masses, can be studied along the SE Anatolian thrust front in the Diyarbakır-Siirt region (İlhan 1967, 1971; Özkaya).

THE TURKISH GREEN ROCK ZONES

Two roughly W-E extending main told patterns can be distinguished in Turkey:

1. The Northern Anatolian Folds representing the northern «Alpides» branch of the orogenic belt linked in the W to the Balkan and Carpathian Ranges and in the E to the Northern Iranian Folds.

2. The Southern Anatolian Folds torming part of the southern «Dinarides» branch which includes the folds of Yugoslavia, Albania and W Greece in the W, the Iraquian and S Iranian Folds in the SE of Turkey.

These two main units are separated, the one from the other, by a tectonic line (a tectonic scar) in Eastern Anatolia; in Central and Western Anatolia, the area between the main branches is occupied by less intensively folded areas being predominantly formed by metamorphic and plutonic rocks, as well as minor fold zones (f. ex. the Aegean Folds) extending in directions being different from that of the main fold zones. The question is still subjected to discussion, if these «intermediate units» form part of the N Anatolian Folds or if they should be considered as an independent system of intermediate massifs and folds (Arni; İlhan, 1971; Ketin, 1966; Pınar & Lahn, 1954).

Ophiolitic series form important longitudinal zones in all the Alpine folds; they form isolated areas in the Central Anatolian Kırşehir Massif, but are absent in the Aegean Menderes Massif.

1. The *Northern Anatolian green rock zone* follows the internal zone of the N Anatolian Folds, from Geyve in the W until East of Sivas in the E, where this zone joins the internal green rock zone of the S Anatolian Folds. From here until the Turkish-Russian frontier in the E, both united green rock zones form the tectonic scar separating the Northern from the Southern Anatolian Folds. At the difference of the S Anatolian Folds, no green rock occurrences exist in the external (northern) zone of the N Anatolian Folds.

2. The *Central Anatolian green rock area* consists of ultrabasic occurrences scattered over the border sectors of the fold fan of Ankara (a promontory of the N Anatolian Folds), along the limits between these folds and the Central Anatolian intermediate massifs.

3. The *green rock zone of the internal Toros Mountains* follows the *internal zone of the S Anatolian Folds;* it forms also the limits between these folds, the Aegean and Central Anatolian intermediate massifs; it joins in the East the N Anatolian green rock zone (as mentioned above).

4. A second, *external green rock zone* is developed in the *S Anatolian Folds* in SE Anatolia, where it forms the thrust front separating Alpine folds and foredeep features; this zone begins in the W in Hatay (its westward extension is probably represented by the ophiolitic rocks of Cyprus) and continues southeastward into Iraq and S Iran. Isolated green rock patches tectonically intercalated between the Paleozoic (and Mesozoic ?) rocks of the Bitlis Mountains in SE Anatolia suggest the existence of a link between external and internal green rock zones in the S Anatolian Folds. (Personal observation by İlhan, recently confirmed by Mason.) In this case, the green rocks must have been moved from here southward to the external thrust front of the folds.

5. In the *Western Anatolian, Aegean and Çanakkale-Gelibolu (Dardanelles) green rock zones,* the maximum development of ophiolites. can be observed in the neighborhood of the tectonic limits between folds and intermediate massifs.

In addition to the main green rock zones, small green rock patches are scattered over the Alpine folds of Anatolia. They may originate in the main zones and have been transported to their actual localities by thrusts or submarine slides. A striking example is the ultrabasic rock mass situated in the Cretaceous flysch series of N Anatolia, in the SW of Sinop (Domuz Dağı area; well record, Petroleum Administration, Ankara).

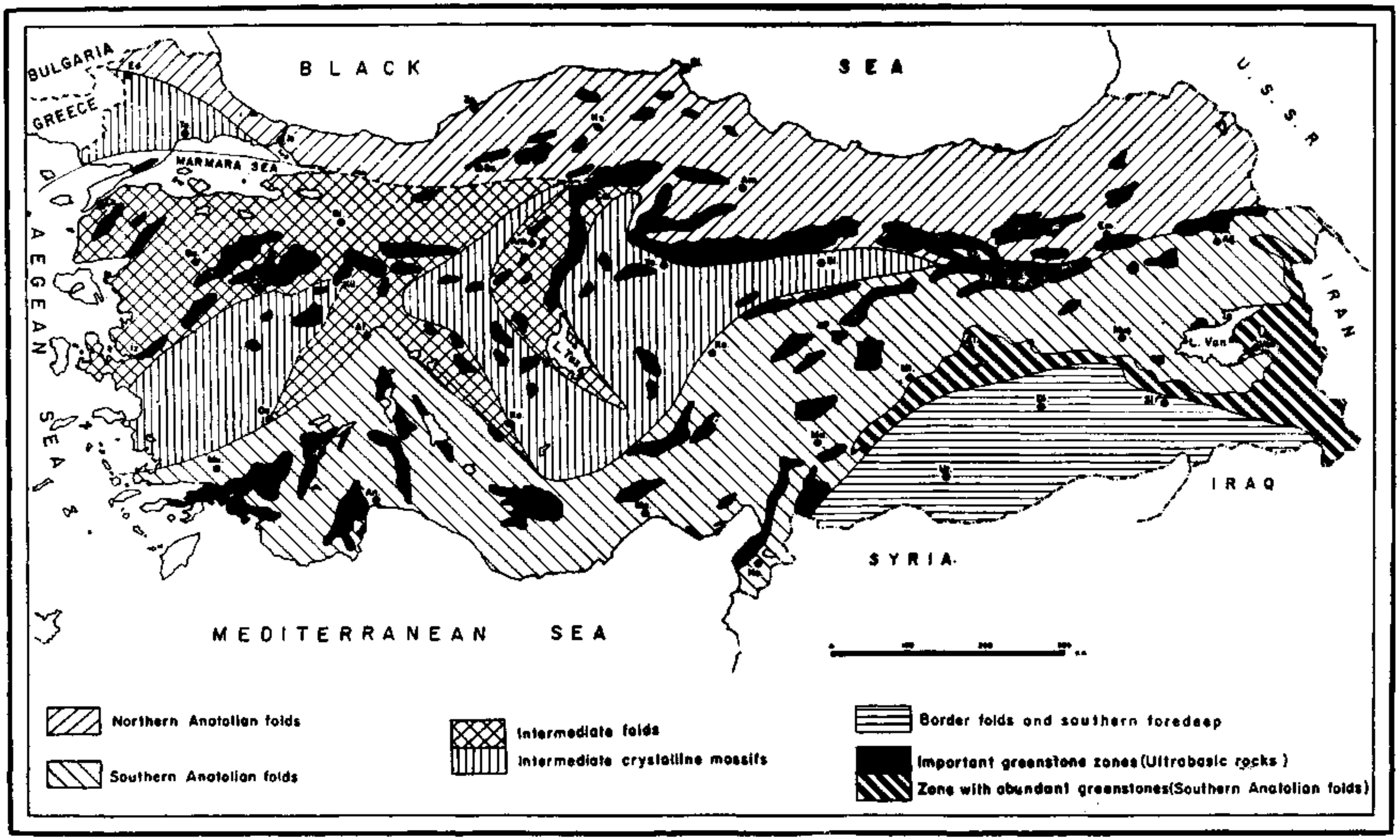

Fig. 2 - Main tectonic units of Turkey (after N. Pınar & E. İlhan, 1954; E. İlhan, 1971).

Abbreviated town names : Ağ - Ağrı, Am - Amasya, Ank - Ankara, An - Antalya, Ba - Balıkesir, Bi - Bilecik, Bo - Bolu, Çk - Çanakkale, Ço - Çorum, De - Denizli, Di - Diyarbakır, Ed - Edirne, El - Elâzığ, Em - Erzurum, Er - Erzincan, Ha - Hatay, İs - İstanbul, İz - İzmir, Ka - Kayseri, Ko - Konya, Ks - Kastamonu, Kü - Kütahya, Ma - Maraş, Me - Mersin, Ml - Malatya, Mu - Muğla, Si - Sivas, Si' - Siirt, Sin - Sinop, Te - Tekirdağ, Tr - Trabzon Ur - Urfa, Yo - Yozgat, Zo - Zonguldak.

East and west extensions of the Turkish green rock zones: In the *East,* the Northern Anatolian and Internal Southern Anatolian green zones continue into the N Iranian Folds and the Central Iranian Intermediate Folds respectively. The external S Anatolian zone extends through the Zagros Ranges (Iraq and S Iran) until the Oman Ranges on the Arabian side of the Oman Strait (see: geological maps of Iraq and Iran).

In the *West,* geologists like Aubouin, Brunn (1961), Kober (1952) and Mercier consider the Vardar - Belgrade Zagreb and Pelagonian - Subpelagonian - Mirdita zones as probable westward extensions of the Northern Anatolian and Internal Southern Anatolian green rock zones, respectively.

POSSIBLE DEEP-SEATED REGIONAL TECTONIC PATTERNS

The above-mentioned data show that the main green rock zones of Turkey are roughly parallel to the main tectonic units of the country and that they follow important tectonic boundaries.

Occurrence and distribution of green rocks in Turkey points to the existence of deep-seated longitudinal dislocations to which the submarine extrusions of these rocks must be related. The distribution of the ultrabasic rocks shows a striking parallelism to the major earthquake zones of the country (see: Pınar & Lahn, 1952). Of course, no direct relation can be supposed between the seismic zones—representing actual features of post-orogenic, epeirogenic fault patterns—and a geosynclinal phenomenon, like occurrence and distribution of green rocks. But seismic patterns may be a more recent surface expression of older, deep-seated tectonic features. These features were responsible, in the geosynclinal stage, for the ultrabasic extrusions and produced, in post-orogenic time, during a period of rejuvenation, the superficial fault zones that are still active.

These deep-seated tectonic features may be:

1) Large longitudinal fault zones. 2) Deep roots of nappes. 3) Boundaries between deep-seated regional units, such as erogenic fold and intermediate relatively unfolded areas. 4) An erogenic belt and a stable foreland. One could imagine that the Northern Anatolian and Internal Southern Anatolian green rock zones correspond to the deep limits between orogenic zone and northern and southern foreland, respectively (with regard to the actual width of the orogenic belt, after the lateral compression due to the Alpine paroxysms). In all these cases the deep-seated limits must be buried below thick piles of overthrusted sediments and rocks.

It may be interesting to note, that the probable westward extension of the Northern Anatolian green rock zone, the Vardar-Belgrade zone, is considered by Aubouin (1960), Brunn (1961) and Kober (1952) as possible root zone separating the Dinarides branch from the Carpathides branch of the Alpine belt. The nature of the probable westward extension of the internal green rock zone of the Southern Anatolian Folds is still discussed (following the same authors): large scale thrusts originating in the Vardar zone, or root zone separating Dinarides folds from the southern foreland.

The supposed existence of deep-seated tectonic features controlling distribution of ophiolites and seismic activity results from stratigraphic and tectonic observations in the country. There are different possibilities to explain the origin of such features:

1. Deep-seated longitudinal fracture zones could be related to the *formation and development of the Alpine geosyncline.* Kober (1942) considered the orogenic belts as «very old scar zones of primary importance)) where successive orogenies occurred. In this case, existent fractural features could have been reopened (rejuvenated) during the Alpine orogeny, and, later on, during young epeirogenic movements. Following Aubouin (1962, 1965), the Alpine ophiolitic extrusions occurred mostly in

the Upper Jurassic, during the deepening of the geosyncline; they are related to longitudinal zones situated on the edges between longitudinal ridges and eugeosynclinal troughs. He considered these fractures as effect of «great generative distensions of the Alpine geosyncline» (followed by later compressional movements).

2. Recently, attempts were made to explain the orogenic patterns, the arrival of the ophiolites and the seismic activity in Turkey and neighboring countries with *«plate movements»;* for example Brinkmann, Çoğulu, Tatar (Turkey) and Takin (Iran). The idea of rigid masses approaching another, dates from the first attempts to explain orogenic phenomena with the contraction theory. The possibility of masses drifting in an unilateral sense was forwarded by Wegener. Therefore, the principles of the «plate theory» are not at all new. These thoughts were modified later on by authors like Argand: the African Block drifting northward over the European Block produced the predominantly northward pushed European Alps, while the Centre-Asiatic («Serindian») Block moving southward created the predominantly southward folded Asiatic sectors of the Alpine belt. Iran and Anatolia form a transition zone between these two patterns and show symmetric features with a northward folded northern and a southward folded southern branch of the «double chain» («orogenic polarity», Aubouin, 1965). Bockh *et al. (in* Gregory) precised the idea of a southward drifting Asiatic Block as motor of the Southern Iranian Folds (Zagros Ranges). Sima masses were squeezed out along the inclined scar planes between the blocks.

In what concerns the application of plate tectonics to the origin of the Turkish and Iranian green rocks, it must be noted that no accordance exists with regard to the sense of the plate drift: Çoğulu explains the uplift of the ophiolites in the Kızıldağ area (Hatay) in Upper Cretaceous times with a southward drift of the Africo-Arabian Block. But following Takin, the northward drift of the same plate was the reason for the arrival of the contemporaneous ophiolites in the Zagros Mountains (situated in the same branch of the orogenic belt, as the Hatay green rocks).

Alternative explanations for the existence of deep-seated important tectonic longitudinal features can be derived from recently advanced theories such as the *anti-clockwise rotational movement of the Arabian Block* (see for example Girdler). The geological situation along the Turkish border section of the Arabic Block (from the Hatay region in the W until the Cizre area in the E) does not offer proofs for the existence of a rotating movement. But, if the rotation is supposed to having occurred in the Upper Mesozoic, then the disharmony between rotated block and stable frame would be buried below the Tertiary deposits. The disharmony which exists between the flanks of the Hatay-Maras. graben, the northward extension of the Dead Sea-Syrian graben (Lower Mesozoic and Paleozoic on the western, Upper Cretaceous and Eocene on the eastern flank; Geol. Map of Turkey 1:500,000, sheet Hatay), south of Maraş, can simply be explained with different vertical displacement on the graben flanks. Only the situation along the flanks of the «Ecemiş corridor» (a narrow S-N directed graben parallel to the Hatay-Maraş graben, situated NW of Adana; Geol. Map of Turkey 1:500,000, sheet Adana) suggests a possible horizontal N-S or S-N displacement.

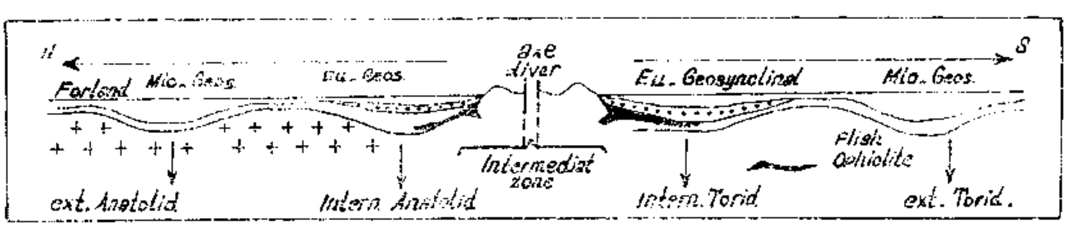

Fig. 3 - Distribution of Anatolian folds (after the schema of Aubouin).

Nevertheless, the type of «bilateral geosynclines» and «orogenic fold ranges with centrifugal symmetry» in the sense of Aubouin (1962, 1965) and Kober (1942), as it is represented by the Turkish sector of the Alpine belt, fits better bilateral compression than unilateral pressure exercised by drifting plates or rotating masses.

An other theory is based on the inference that substantial *horizontal displacements have taken place along longitudinal regional faults* in the orogenic belt (Brunn, 1961). The disharmony of the Anatolian segment of the orogenic belt—the Northern Anatolian Folds are straightly W-E extending, but the Southern Anatolian Folds form large arcs with complicated joints—may be responsible for such supposed movements. This inference is encouraged by horizontal displacements reported from earthquakes along the Northern Anatolian earthquake zone (several cm to 3-4 m; see for example Pınar & Lahn, 1952).

CONCLUSIONS

The ultrabasic rocks of Turkey are of Lower Mesozoic age, but they were at least partially displaced, together with their associated sediments, during the Upper Cretaceous paroxysm, by both thrusts and submarine slides. The possibility of an Upper Cretaceous age of the ophiolites situated along the external border of the S Anatolian Folds (from the Hatay to the East) is still discussed.

The main green rock zones of Turkey are roughly parallel to the main tectonic units of the country and seem to follow important tectonic boundaries. In addition, they show a striking parallelism to the major earthquake zones.

All these facts make suppose that the occurrence of ophiolites is related to deep-seated longitudinal dislocations which were rejuvinated in post-orogenic time and produced then the superficial fault zones that are still seismically active.

Various explanations can be forwarjded for the origin of these deep-seated dislocations: formation and development of the geosynclinal trough in the sense of Aubouin and Kober; drift of plates; rotative movement of the Arabic Block; longitudinal displacements along important faults. The validity of these theories—conventional as well as unconventional ones—cannot be assessed by observations made in Turkey alone. But in future discussions, various possibilities of crust movements should be taken in consideration.

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Photo 1

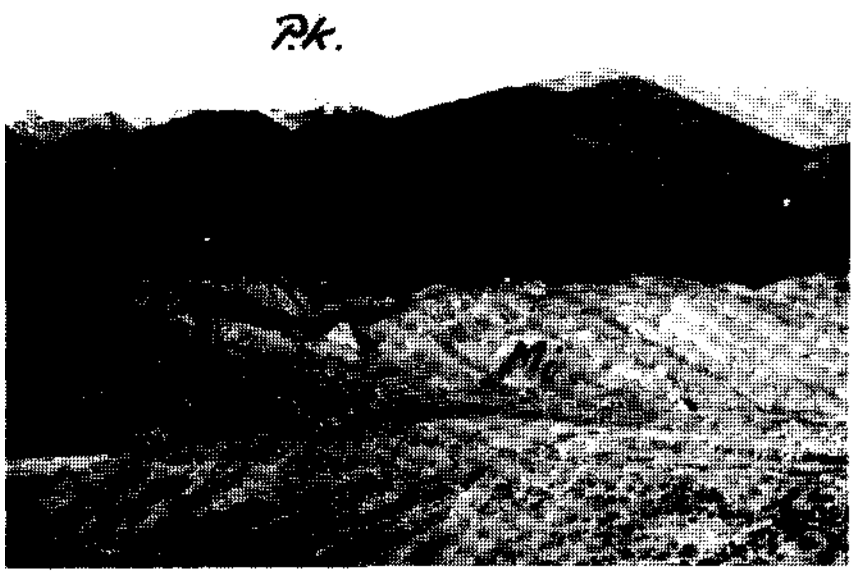

Photo 2

Photo 1-2 - Permo-Carboniferous limestones (P.k) pushed over the green rock series (Ye. ka.); the latter thrusted over Miocene (Mi) deposits. Thrusts directed from N (background) to S (foreground); P.k. and Ye. ka. form the front of the Southern Anatolian Alpine Folds; the Miocene covers the foredeep of the orogenic belt in SE Anatolia (near to the district center of Sason).

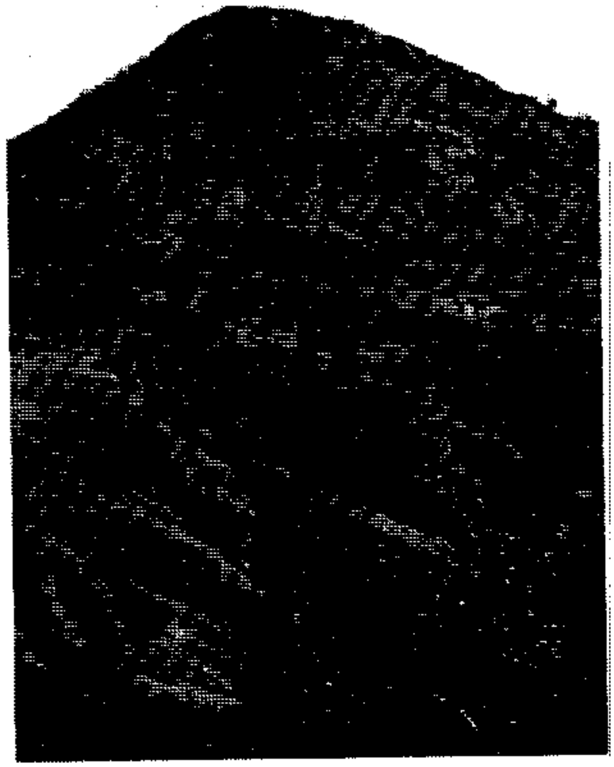

Photo 3 - Detail of 1 - 2.

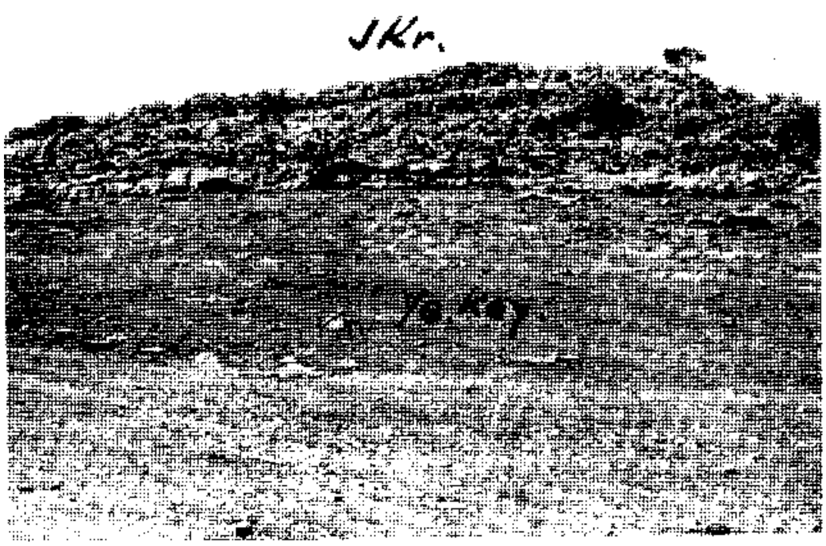

Photo 4 - Upper Jurassic - Lower Cretaceous limestones (J. Kr.) covering green rocks (Ye. kay.); normal stratigraphic succession, NW of Cihanbeyli, near Yeniceoba (Central Anatolia).

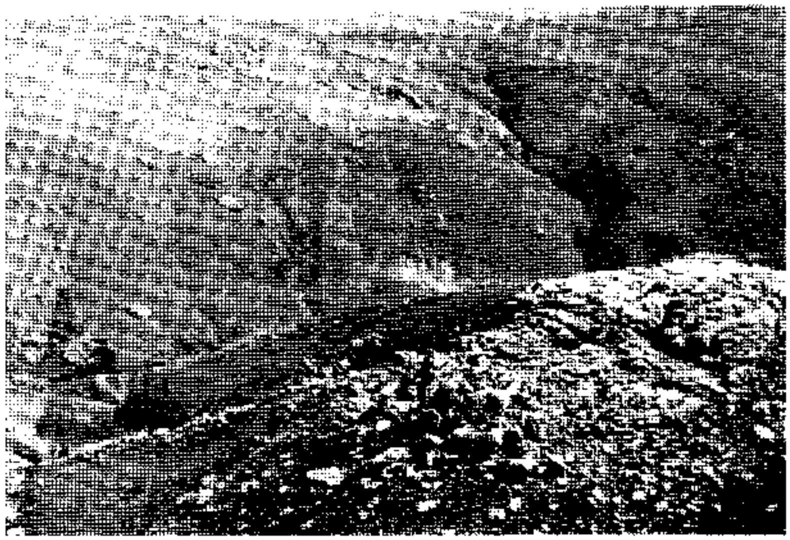

Photo 5

Photo 6

Photo 5-6 - Limestone blocks of Permian, Triassic or Jurassic age forming tectonic intercalations in the green rock series. Elmadağ E of Ankara, Northern Anatolian Folds (fan of Ankara).

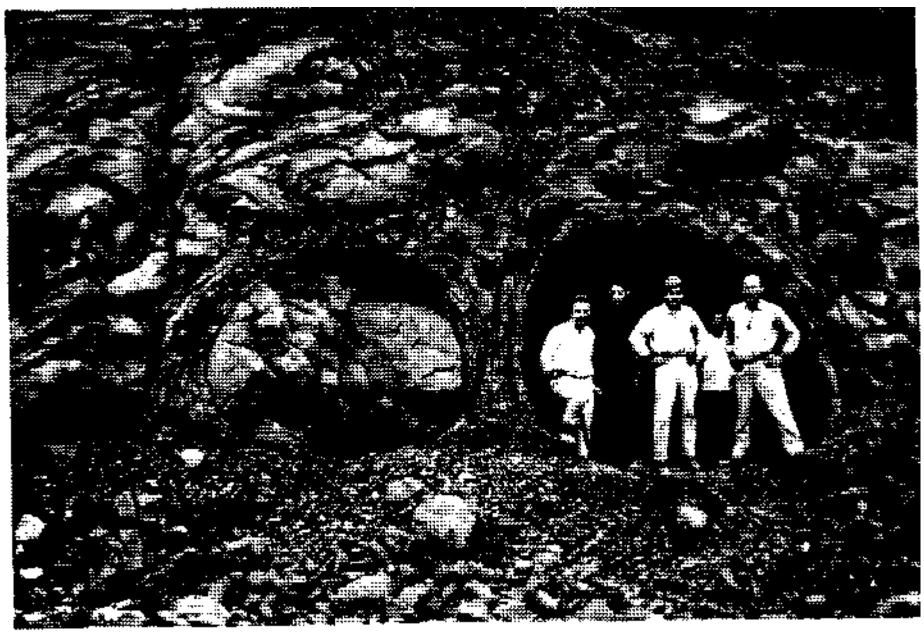

Photo 7 - Weathered pillow lavas interstratified between Upper Cretaceous clastics (no green rocks) representing the Upper Cretaceous volcanism. Giant boulders in the lavas (Black Sea coast, E of Amasra, Northern Anatolian Folds).

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