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ECONOMIC POTENTIAL OF RESIDUAL DEPOSITS IN PENEPLANATED AREAS IN TURKEY

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ECONOMIC POTENTIAL OF RESIDUAL DEPOSITS IN PENEPLANATED AREAS IN TURKEY

Kenan TÜFEKÇİ *

ABSTRACT.- Peneplain is a geomorphological unit which is formed in the final stage of the fluvial denudational cycle. The developed peneplains on the bedrocks of containing iron, olivine, pyroxene, feldspar or fcldspalhoids comprise lateritic ore deposits. Besides the bedrock, the formation of this residual deposits arc due to both tropical climate and nonactive tectonic conditions. Today, actual lateritizations has been going on in the climatic bells where tropical climate conditions are dominant in the world. But it isn't impossible to bring up that the lateritization has been lasting under actual climatic influences in Turkey. Paleoclimatological conditions in the geological past arc important for Turkey. For this reason, especially, the cycles of Upper Cretaceous and Lower to Middle Miocene in Turkey are suitable climatic cycles to lateritizations in Turkey, the relics of the oldest relief forms pertaining to Upper Cretaceous and the relics of "Anatolian Peneplain" pertaining to the denudational cycle of the Lower to Middle Miocene may be very interesting for residual ore deposits. When Turkey's tectonic evolution is appraised from this view point: while the Pontides, the Anatolides and Tauridcs in places appear to be the suitable belts, but not the Border Folds region. As a result, it isn't impossible to have enough knowledge about the residual deposits and their peneplanation cycles from the present surveys in Turkey. Consequently, the evolution of the residual deposits isn't known with details yet. For this reason, the prospection of the deposits must be planned by amulti-disciplinerprogramme. Geomorphologically, the extend of the deposits must be mapped and their relations with the geomorphologic units must be explained.

INTRODUCTION

It is a fact which has been slated al many panels on carlhsciences that the future of a country's industry could be secured by providing its required raw material and energy domestically. For this purpose, new natural resource exploration methods and theses are being developed and exploration process is now considered as an interdisciplinary program. That latcritic ore deposits which are the object of this research have not been explored in detail in Turkey, except the Çaldağ (nickel) and Seydişehir (aluminum) areas, makes the prospection of ore deposits more interesting.

Besides the characteristics of bedrock, the factors such as climate, topographic features, and geomorphologic evolution have also an imporiant effect on the formation of the residual ore deposits. The bedrocks containing iron, olivine, pyroxene, feldspar and feldspalhoid minerals are gradually turned into the residual ore deposits by simultaneous formation of peneplancs and a thick leaching zone forms in the peneplanes in tropical climates. However, change in climate or the end of tectonic stability during the peneplanation may change the position of the formed or yet-to-be formed residual ore deposits.

In this paper, the residual ore deposits are investigated geomorphologically and the morphogenetic and morphoclimalic factors affecting the formation of these deposits in Turkey are also reviewed.

CONCEPT OK PENEPLANE AND THE CHARACTERISTICS OK RESIDUAL ORE DEPOSITS FORMING IN PENEPLANES

In order to form residual ore deposits in an area, addition to tropical climate, a period of tectonic stability, that is, a peneplane formation period is required. Therefore, first of all the concept of peneplane and the characteristics of peneplanes should be briefly considered. The term "Peneplain" was first used by Davis in 1889 referring to a nearly fcaturless, gently undulating land surface of considerable area, which presumably has been produced in the penultimate stage of a humid fluvial geomorphic cycle (Erinç 1982). According to Davis, flat areas which are gently undulating and spread over considerable areas are produced as a result of millions of year-long erosion of internally weakened formations (Fig. 1). Peneplane is such that the original topographic relief has been eroded down, the intensity of mass movements is lesser, the streams carry smaller quantity of materials and slow down due to the small quantity of strcamload. These gcomorphologic units, known also as Truncated Plane", are distinguished from denudational planes by their greater size (Ardos. 1971). The residual ore deposits form in this geomorphologie unit, the characteristics of which is briefly discussed above,

Peneplanes may be subjected to tectonic deformation during/after formation. Tectonic movements may rip these units by hundreds of meter deep trenches and cause the laterite deposit, which are in the peneplane, to be eroded and rede-

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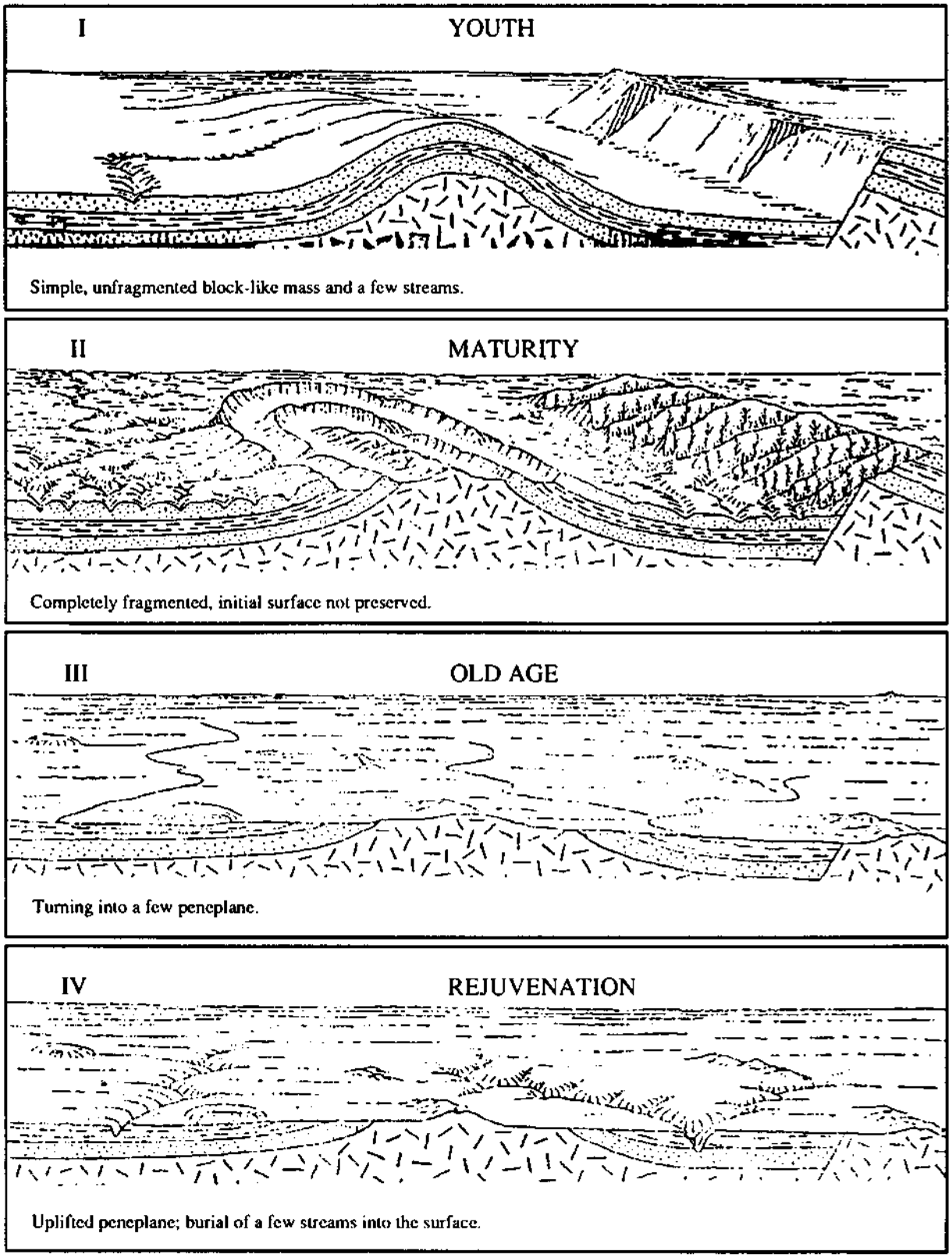

Fig. 1- Stages in geomorphic cycle in a humit area.

posited in various environments. It has been determined that today some of the ancient peneplanes have been folded or depressed, some of them have been eroded down to the sealevel and some others have been fossilized by younger sediments which cover them. For instance, the bauxite deposits in Arkansas formed in pre-Eocene peneplanes and are locally blanketed by the Tertiary claystones and sandstones (Özkoçak, 1980). The bauxite deposits in Şarkikaraağaç-Yalvaç, Akşehir, on the other hand, formed in diabase and were fossilized by the overlying Upper Jurasic limestones (Özkoçak, 1980). As a result of erosion of the sediments covering these fossilized peneplanes, the ancient surfaces can be determined as exhumed surfaces.

Lithology of the rock in which peneplane developes is also important. Although these deposits form in different type of hostrocks in humid climates, for residual iron deposits, especially the ultra-basic rocks with low aluminum content for nickel deposits, dunite, peridotite and pyroxenile, and for the residual bauxite deposits, feldspar or feldspathoid bearing rocks arc important (Özkoçak, 1973, 1980; Cornwall, 1973). The examples to this type of deposits are those; after the sub-oceanic basalt-andesile flow in the Late Oligocene or the Early Miocene in New Caledonia there occured great peridotite emplacement. This ultrabasic massif, dominated by harzburgite, was uplifted above the sea level and peneplanated, over 50 m thick iron laterite blanket formed in it in a tropical climate (Özkoçak, 1980). In the above-mentioned climate, the peneplanes forming in dunites, peridotites and pyroxenite are also suitable for the formation of the residual nickel deposits. Vinogradov (1956) estimated that the average nickel content of these rocks is 0.1-0.3 %. Whereas Golightly (1979) listed the factors necessary for the formation of the residual nickel containing deposits as follows: 1- Mineralogy and tectonic emplacement of peridotite; 2- Climate; 3- Topographic relief; 4- Geomorphologic background. It is a fact that economic residual deposits can be mined in the peridotitic areas which were peneplanated in tropical climates. However, it is necessary to assert that there have been periods of laterite forming conditions in geologic times similar to the actual laterite forming conditions. This type of a period occured in Turkey as well as in the other parts of the world during the Middle Tertiary and Upper Cretaceous. Although the hostrocks vary in type in the formation of the residual bauxite deposits the peneplanes forming in feldspar and feldspar rich rocks are especially suitable.

The relationship between the bauxite residual deposits and hostrocks can be shown on several examples around the world: The deposits forming in nepheline syenites arc found in Arkansas, Brazil, Guinca and Los Islands; the deposits forming in basalts and dolerites (diabases) are in India, Germany, Scotland, Guinea and Cameroon; the deposits forming in metamorphic schists arc in Guyana Ghana, Guinea and Ivory Costs; the deposits forming in sandstones are in Nigeria. Bauxite deposits forming in carbonaceous rocks are found commonly in Spain, France, Italy, Grece, Yugoslavia and Turkey, that is, around the Mediterranean Sea (Özkoçak, 1980).

As can be seen, the formation of the residual deposits is related not only with hostrock but also with the peneplanation processes. Another effect is suitable climate which produces leaching zone in the peneplanes.

RELATIONSHIP BETWEEN THE RESIDUAL DEPOSITS AND CLIMATE

Another factor I mentioned above for forming residual deposits is climate. These deposits form in the morphoclimatic regions which have tropical climate. Persons (1970) showed the relationship between temperature and precipitation for latcrite formation on a plot (Fig. 2). It is seen on the plot that the average temperature and rainfall for the formation of laterite deposits vary between 18.3-30.0 degree centigrade and 50.8-228.6 centimeter, respectively. According to Golightly (1979) annual rainfall is 159-300 cm.

The formation of the laterite deposits still continues in the tropical and subtropical areas, such as Solomon Islands, Philippines, Cuba, Venezuella, Puerto Rico, Dominica, New Caledonia, Australia, India, Brazil, Guatemala, Indonesia, which have economic residual deposits.

The current climate types in Turkey, some of which are the Mediterranean, Black Sea, and continental climates, are not suitable for the formation of the residual deposits. The average temperatures in the sectors with these climates are as such: The average annual temperature from the Mediterranean cost to the Urfa district 18°-19°C, around the Agcan cost 15°-18°C, along the Marmara Sea and the Black Sea 13°-15°C and in the central Anatolia, 11°-13°C. On the other hand, the highest amount of annual rainfall is in the eastern Black Sea region (higher than 2 m). In the western Black Sea region and the western Mediterranean region and around the Hatay district, the annual rainfall is 1-2 m; in the Aegean and Marmara regions and in most of the eastern Anatolia, the annual rainfall is 0.5-1 m.

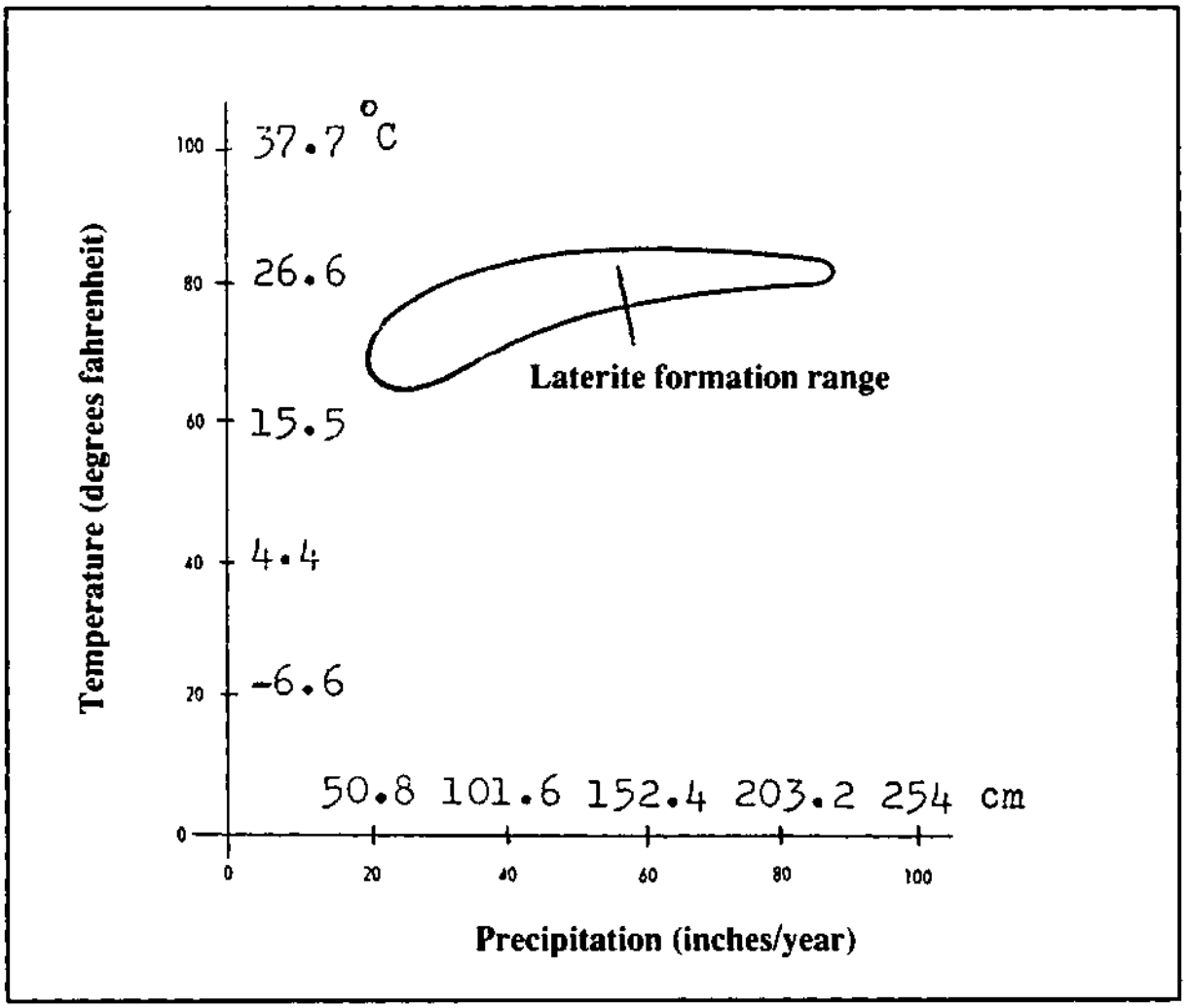

Fig. 2 - Precipitation-temperature relation in laterite formation. Temperatures converted into °C and precipitation values converted into centimeter.

The average temperatures and rainfall in Turkey are lower than the temperatures and rainfall given in Persons (1970). Therefore an actual laterite deposit formation seems not possible in Turkey.

Kurter (1979), who distinguished four effective chemical weathering types in Turkey by using climatic data, pointed out that the eastern Black Sea region has the most intensive chemical weathering. Although the rainfall is quite high in this region temperature is not as high as the tropical regions. Kurter (1970) stated that no part of Turkey has humid tropical conditions. As a result of this, today's climatic conditions have not allowed any lalerite formations in Turkey.

However, besides the actual laterite belt. Riddle Oregon, USA, which formed in laterized plato remnants and the Arkansas bauxite, which formed in a pre-Eocene peneplane and fossilized under the Tertiary sediments (Özkoçak, 1980) are the evidences showing that the necessary climatic conditions were dominant to form residual deposits in North America in the past as it is the case with the actual residual deposits to form residual deposits. In the Mediterranean basin, on the other hand, the nickel laterites in Yugoslavia and Grece have been fossilized by the Cretaceous limestones or Tertiary sediments (Golightly, 1979). In Turkey. 50 m thicklateritic nickel deposits in Çaldağ, Turgutlu (Yıldız, 1977, 1981), the lateritic belt in serpentinitcs around Sivrihisar (Boyalı, 1984; Boyalı and Koç, 1986), the lateritic nickel deposits in Orhaneli, Bursa, although

not very typical (Wilson, 1976), various iron laterites in Erzincan, Sivas, Malatya, Hatay and Ankara (Özkoçak, 1973), the nickel laterite in Frankenstein (Silesia), the allochtonous bauxite deposits in northern Urals, USSR, are the evidences indicating that suitable climatic conditions were also dominant in Asia, Europe and Anatolia in the past as in the North America.

As shown by the examples around the world, it is necessary to know Turkey's paleoclimatic characteristics in order to shed a light on the laterite forming conditions in Turkey. According to the characteristics which have been determined by various authors, while the tropical climate was dominant during the Cretaceous period in the Early Paleocene the climate was warm around the world but later the temperature dropped gradually. In the Eocene, contrary to the Paleocene, the climatic conditions were more evident and around the poles the climate was similar to the temperate climates of today. However, both climate and temperature were higher than the current temperatures of the temperate climates. In the Oligocene, finally, the winters were cooler and the difference between rainy and dry seasons was more evident. The Early and Middle Miocene were periods when a warm humid climate was effective in Turkey for a long time and also an "Anatolian Peneplane" developed in this climatic condition. Contrary to the arid and semi-arid climate in the Upper Miocene, in the Pliocene, a humid-warm climate was effective. During the Early Pleistocene epoch, warm climate withlower humidity was interrupted by short cooler-and-rainy periods.

Consequently, the paleoclimatic data indicate that warm-humid (tropical) climates during the Cretaceous period (specifically the Upper Cretaceous) and the Early-Middle Miocene were the right conditions to form residual deposits in Turkey.

RELATIONSHIP BETWEEN THE TECTONICS AND THE RESIDUAL DEPOSITS IN TURKEY

A relationship between the tectonic activity and the formation of residual deposits in a region should be expected. It is possible to assert that residual deposits form in the rocks in suitable climatic conditions when these rocks are uplifted above the scalevel by tectonic movements. Therefore it is necessary to review briefly the tectonic evolution of Turkey. As it is known, studies have been done for a long time in order to distinguish the tectonic units and determine the tectonic evolution in Turkey (Ketin, 1966). According to the tectonic units of Anatolia which was established by Ketin (1966, 1983), the oldest mountains, the Caledonian and Hercinian massifs, which are located in the Pontides were like islands in the Tethis Sea while the other regions of Anatolia were mostly under the scalevel at the beginning of the Mesozoic Era. The Anatolides developed at the end of the Cretaceous period and were the second in the tectonic evolution. The Torides developed at the end of the Oligocene. The Margin Folds, on the other hand, completed their evolution from the Late Miocene to the Early Pliocene. Therefore it can be asserted that the tectonic-orogenic development in Anatolia was from north to south, and the Pontides, Anatolides, Torides and the Margin Folds developed as mountain bells in this order (Ketin, 1966, 1977, 1983).

As the briefly-reviewed tectonic evolution is assesed regarding the residual deposits it can be asserted that the Ponlidcs, Anatolides and Torides might have been affected by the tropical conditions during the Cretaceous and the Early-Middle Miocene whereas the Margin Folds arc not promising for the development of laterite deposits.

RELATIONSHIP BETWEEN THE EROSION-DEPOSITION PERIOD AND THE RESIDUAL DEPOSITS IN TURKEY

Some regions of Anatolia were uplifted above the scalevel by the tectonic movements that took place from the Upper Cretaceous to the Eocene (Ketin, 1959), however, the actual morphology of Turkey began to form in the Oligocene and completed during the Neogene and Quaternary by internal and external forces (Erol, 1980). However, this process was interrupted by the general tectonic movement and a silence period and also by the changes in the climate. In accordance with this, a geomorphologic evolution occured as erosion and deposition periods lasting from the Late Oligocene to the Pleistocene. According to the principles suggested by Erol (1980, 1983) and the results of the geomorphological studies conducted in the framework of these principles, the erosion-deposition periods that took place in Turkey can be briefly determined as follows:

The oldest geomorphologic remnants belonging to the Upper Cretaceous (DF system).

The Upper Oligocene crosional surfaces (DO systems).

The Lower-Middle Miocene period (D I systems).

The Upper Miocene period (D II systems).

The Pliocene period (D III systems).

The Lowermost Pleistocene period (D IV systems).

The Lower and Upper Pleistocene period.

The Holocene period.

Among these periods, the oldest geomorphologic remnants of the Upper Cretaceous and the crosional surfaces of the Miocene arc significant for the formation of residual deposits. The north and northwest Anatolian mountain ranges were like islands in the Tethis Sea even in Mesozoic, and then, they were raised totally above the scalevel by the tectonic movements in the Oligocene to form that part of Anatolia where the oldest geomorphologic units may be found. The central Anatolian mountain chain, which was subjected to the first intensive orogenic movement at the end of the Cretaceous period and was raised above the scalevel at the end of the Eocene, is an orogenig belt in which relatively younger old-geomorphologic remnants may be found. However, since these units have continuously been eroded since their forming, it is not very probable that these old remnants be preserved. But still, the remnants of the former erosion surfaces in the Cretaceous period have been detected as fossils and some smaller parts of these remnants crop out in some areas where the covering rocks were eroded away (Erol, 1980).

On the other hand, a new erosion-deposition period started over Anatolia by a scries of tectonic movements at the end of the Oligocene and a peneplanc called the Anatolian Peneplanc developed under tropical conditions of this periods. Thus the existence of the remnants of this peneplane has been proven by the geomorphologic studies conducted in various parts of the country (Bilgin, 1969; Atalay, 1977, 1978, 1983; Erol, 1980. 1981, 1983; Kozan et al., 1982; Özgür, 1983; Durukal et al., 1984, 1985; Tonbul, 1986; Tüfekçi, 1987). This erosion-deposition period regarding the laterite deposit is important for Turkey. In this period, the Anatolian Peneplane, which developed under the tropical conditions, was eroded almost down to the scalevel. It is then, possible to assert that a deep leaching zone in this peneplane formed during the crosional period.

As a result, as the erosion-deposition periods are reviewed in respect to the residual deposits in Turkey, the erosion surfaces of the Lower-Middle Miocene (D I systems in Erol, 1980) which started to develope first in Anatolia under the tropical conditions in the Lower-Middle Miocene and were affected by neotectonic movements are significant regarding the formation of the residual deposits. Furthermore, the old geomorphologic remnants of the Upper Cretaceous (DF systems) which arc detected as fossils arc also promising in regard to the residual deposits.

RESULTS

The residual deposits form by peneplanation of the hostrocks containing iron, olivine, pyroxene, feldspar or feldspathoid under the tropical conditions, and by formation of a deep leaching zone in the forming peneplane. This leaching zone is closely related with tectonic stability. In the case that tectonism starts to activate, the residual deposits arc totally or partially eroded and redeposiled in known depression areas to form secondary (allochthonous) deposits. In the world and also in Turkey, the Upper Cretaceous and Lower-Middle Miocene had suitable conditions for the formation of residual deposits. Today, while laterization continues in the tropical bell, actual laterization does not occur in Turkey, for Turkey has no more tropical conditions. On the other hand, the formation of these deposits is also related with tectonic evolution of Turkey. Therefore certain parts of the Pontides where the first and intense orogenic movements occured should be expected to have laterizated under the tropical conditions in the Cretaceous period. During the Lower-Middle Miocene this belt also had the similar climatic conditions. Although the Anatolides and Torides may also be thought to have been affected by the tropical conditions in the Cretaceous period the important role was of the conditions in the Lower-Middle Miocene. The Margin Folds, which were affected by intense orogenic events at the end of the Miocene are not promising for the formation of laterile deposits. In the formation of these deposits; hostrock; climate; topographic features; geomorphologic evolution have significant role. However, there has not been enough information collected in the studies on laterile deposits in Turkey regarding the relationship between the residual deposits and the peneplanation periods and thus the evolution that these deposits have gone through is not known in detail. Therefore, besides the already available methods, the geomorphologic methods should also be

considered, the evolution and relations with the geomorphologic systems should be determined, and the distribution of these deposits should be mapped. It is clear that this type of studies will contribute to the prospection of the primary, secondary and fossil laterite deposits.

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