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Notes on the Geology and Mineral Resource Potential of Selected Turkish Bauxite Deposits

Alexander Horkel*

2 Text-Figures

Central Taurus Mountains
Amanos Mountains
Seydisehir-Akseki
Bauxite resources
Bauxite deposits
Ayranci
Islahiye
Turkey

Contents

Zu Geologie und Ressourcenpotential ausgewählter türkischer Bauxitlagerstätten

Zusammenfassung

Bis zur Zusammenfassung des montanwirtschaftlichen Potentials der gesamten türkischen Erzlagerstätten durch Yigit (2009) fand sich in der internationalen Literatur nur wenig über die türkischen Bauxitlagerstätten, obwohl bereits Walter E. Petrascheck und Anton Egger in den 1960er Jahren grundlegende Pionierarbeit zur Erfassung des Lagerstättenpotentials der türkischen Bauxite leisteten.
Diese Bauxitlagerstätten sind praktisch zur Gänze allochthone Karstlagerstätten bzw. Lagerstätten an stratigraphischen Diskordanzen und bilden Lager oder Taschen in permo-triassischen bis oberkretazischen Karbonatserien. Die Lagerstätten mit dem montangeologisch interessantesten Ressourcenpotential liegen im Taurusgebirge in der südlichen Türkei oder im Amanosgebirge nahe der syrischen Grenze. Es sind dies:
- die kretazischen boehmitischen Bauxitlagerstätten von Seydisehir mit den größten Bauxittagebauen der Türkei, welche die türkischen Aluminiumindustrie versorgen,
- die permotriassischen Lagerstätten von diasporitischem Bauxit bei Ayranci, als größter türkischer Produzent von nicht-metallurgischem Bauxit, sowie
- die bisher unerschlossenen Lagerstätten von kretazischem eisenreichem Bauxit bei Islahiye.

Abstract

The Turkish bauxite deposits are basically all karst-type allochthonous or unconformity-type deposits, and occur as pockets or layers in Permo-Triassic to Upper Cretaceous platform carbonate sequences. The main bauxite deposits are located in the Taurus mountains of southern Turkey or in the Amanos mountains near the Syrian border. The deposits with the most interesting economic potential are:
- the Cretaceous boehmitic bauxite deposits of Seydisehir with the largest bauxite mines of Turkey, which supply the Turkish aluminium industry;
- the Permo-Triassic diaspore bauxite deposits of Ayranci, which are the largest Turkish producer of non-metallurgical bauxite; and
- the Cretaceous ferrous bauxite deposits of Islahiye, which are awaiting development.

* Alexander Horkel: Zedlitzgasse 11, 1010 Wien, Austria.

Introduction

The geology and mineral resources of the Turkish bauxite deposits were rather unknown in the international literature until a recent summary of the overall mineral potential of Turkey by Yigit (2009). In the past, the state mining corporation Etibank controlled the entire production of bauxite and aluminium through its subsidiary Eti Aluminium under the etatistic-regulatory political system inherited from the foundation of modern Turkey. Only recently, a liberal mining law and the privatization program of the last decade created an enabling investment climate (Beinhoff et al, 1999), which increasingly attracted foreign investment in the mining sector (Yigit, 2009). Today, Turkey is a world class producer of boron (world no. 3 with a global production share of 20 %), feldspar (world no. 2 with a global share of 16 %), magnesite (global rank no. 3), chromite and perlite (global rank no. 4), as well as barite, bentonite and kaolin (all global rank no. 9). Turkey is also the world no. 3 lignite producer (WMD, 2009).

Until the promulgation of the liberalized mining law, mineral exploration by the private sector was insignificant, and the mineral exploration and inventarization of Turkey was primarily the task of the Turkish Geological Survey (MTA), often in technical cooperation with state institutions from other countries, such as Austria.

Within the frame of this cooperation, several well-known Austrian geologists, such as (in alphabetical order) A. Egger, T. Gattinger, H. Holzer or W.E. Petrascheck were engaged in mineral exploration and regional geological surveys during the late 1950s and early 1960s. Their work, however, is either unpublished in the archives of the MTA or published only in Turkish, and therefore, they have not yet received the recognition due to their pioneering achievements.

General Geological Background

Main Paleotectonic and Structural Units

The following summary of the overall geological frame of Turkey is based on the recent work of Bozkurt & Oberhänsli (2001), Gorur & Tuysuz (2001), Moix et al. (2008) and Yigit (2009).

The complex geology of Turkey is the result of the evolution of the Tethys belt, caused by the convergence of Laurasia and Gondwana. Turkey consists of numerous microterranes, separated from each other by complex suture zones, which represent remnants of Paleo- and Neotethys. In terms of terranes, Turkey consists essentially of the following major tectonic units:

The Pontide terrane in the north, comprising:

- Strandja zone and Istanbul-Zonguldak zone, which are part of the southern Laurasian continental margin; and
- Sakarya zone, a mobile metamorphic belt with Laurasian affinities.

The Izmir-Ankara-Erzincan suture, resulting from the closure of the northern branch of Neotethys (Vardar Ocean), separates this terrane from the Anatolide-Tauride platform, which consists of the

- Kirsehir block, a metamorphic basement complex in central Anatolia, which is already part of the Gondwana realm; and the
- Menderes-Taurus platform, a crystalline basement with Paleozoic to Tertiary sedimentary sequences, which contains characteristic thick Permo-Mesozoic carbonate platforms.

The Bitlis-Zagros suture, caused by the collision of the Arabian platform with Eurasia, separates this terrane from the

- Arabian platform with border folds and ophiolite complexes, which forms a part of the Gondwana continental margin.

These first order paleotectonic units were parts of the Laurasian or Gondwana continental margins, or isolated microterranes within the Neotethys. Age, facies, and faunas of the Istanbul Zone differ markedly from the Gondwanan Taurides, and have affinities to Western Europe (Dean et al., 2000); this indicates most probably a location along the margin of Laurasia, while the Anatolide – Tauride microcontinent formed the margin of Gondwana (Tolluoglu & Sümer, 1995).

The complex suture systems and ophiolite belts separating the main tectonic units represent remnants of Paleotethys and of the numerous branches of Neotethys, which started to open in the early Triassic and closed finally during the late Cretaceous to Paleogene. These subduction processes created magmatic arcs, arc-related sedimentary basins, and large-scale ophiolite obduction. Details of the complex geological evolution of Turkey pose numerous highly interesting aspects awaiting further investigations; they are, however, beyond the scope of this paper.

Major Bauxite Districts

Yigit (2009) provides a summary of the Turkish bauxite deposits, including reserve figures from compilations of government-verified reserves and resources by the geological survey (Ersencen, 1989). The following description is based therefore on Yigit (2009), unless stated otherwise.

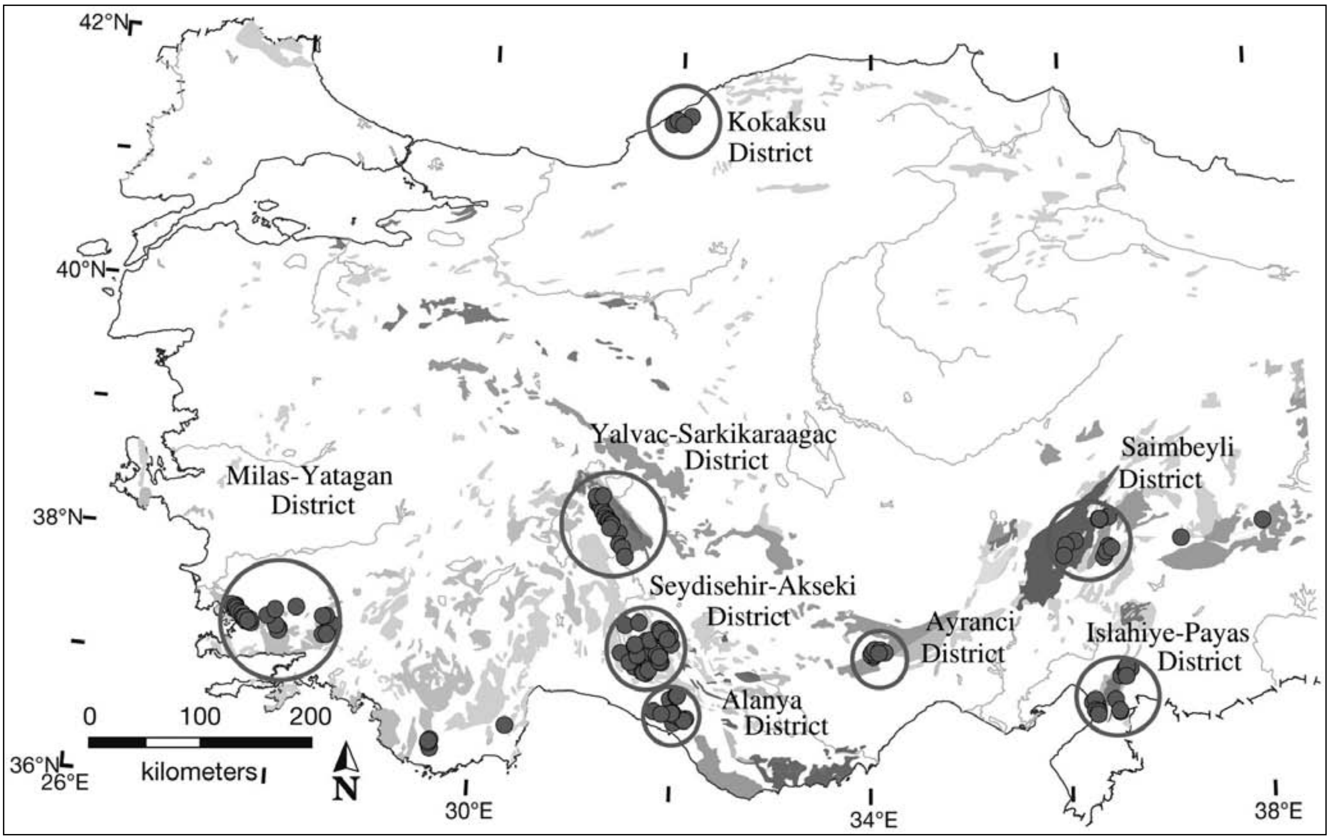
Practically all Turkish bauxite deposits are karst-type allochthonous or unconformity-type deposits, and occur as pockets or layers in Permo-Triassic to Upper Cretaceous carbonate sequences. Autochthonous lateritic bauxite is reported only from one deposit.

Except for the Kokasu district in the Laurasian Istanbul-Zonguldak zone on the Black Sea with a relatively small resource potential of low-grade boehmitic bauxite, the main bauxite deposits occur in the Taurus mountain belt of southern Turkey, or in the Amanos mountains between the Taurus range and the Syrian border (Text-Fig. 1).

The western Taurus range hosts the bauxite district of Milas-Yatagan, which contains numerous small to medium-sized diaspore-corundum deposits, with a combined total resource potential of about 73 mill. t. This district has currently no significant production.

The central Taurus range contains the most significant bauxite resource, occurring in the districts:

- Yalvac,
- Seydisehir – Akseki – Alanya,
- Ayranci, and
- Saimbeyli.



Text-Fig. 1.
Location map of the major Turkish bauxite districts (from Yigit, 2009).

The Yalvac district, with a resource of about 29 mill. t ferrous bauxite at 42 % Al_2O_3 has no production, and hosts the only known deposit of autochthonous lateritic bauxite.

The Seydisehir-Akseki-Alanya district is of major economic importance and was investigated in the early 60's by A. Egger, who produced an unpublished detailed map of the regional geology of the area. The Seydisehir deposits have a total resource of 26.3 mill. t high-alumina boehmitic bauxite at 55–67 % Al_2O_3. Here, the two largest bauxite open pits of Turkey supply the only aluminium smelter of the country. The Akseki deposits near Seydisehir contain also high-grade boehmitic bauxite with a total resource of 17.5 mill. t at 47–66 % Al_2O_3. This resource occurs in numerous smaller ore bodies, and was not developed in the past, as the Seydisehir deposits are more advantageous in terms of infrastructure and economies of scale. The Alanya deposits contain only about 4.5 mill. t diaspore bauxite at 37–67 % Al_2O_3, and are currently of no economic significance.

The diaspore bauxite resource of the Ayranci district amounts to about 4 mill. t high-grade ore at 57.6 % Al_2O_3 (Yigit, 2009), or to 10 mill. t at 53 % Al_2O_3 (Birön & Atak, 1986). Mining started in 2001. Today, the district is the largest Turkish producer of non-metallurgical bauxite (Industrial Minerals, 2009).

The Saimbeyli district contains diaspore bauxite with a total resource potential of about 11 mill. t at 50–52 % Al_2O_3, and has no production.

In the Amanos range near the Syrian border, bauxite occurs in the Islahiye-Payas district. These deposits were already investigated by Petrascheck (1965). Islahiye hosts ferrous Ti-rich bauxite, with a total resource of 96 mill. t at 41 % Al_2O_3, and Payas a resource of 66 mill. t low-grade bauxite at 20 % Al_2O_3. No significant production has taken place so far in this district.

Geological Frame of the Deposits in the Menderes-Taurus Platform

General Geological Frame

The Menderes-Taurus platform consists of several tectonic sub-units with lower Paleozoic to lower Tertiary platform, continental margin, and ocean floor sequences. These subunits are distinct in terms of stratigraphy and metamorphic features, have complex internal structures, and were tectonically juxtaposed during the Senonian to Lutetian. In western Turkey, they include from N to S a blueschist belt, a flysch zone, a major greenschist-facies Palaeozoic–Mesozoic sedimentary zone, and a Precambrian basement with polyphase metamorphism, which is overthrust by Mesozoic carbonate-facies nappes with the bauxites of Milas-Yatagan. These southern nappes pass towards east into the autochthonous, para-autochthonous, and allochthonous units of the Central Taurus and the Anti-Taurus. These units are characterized by thick neritic Permo-Mesozoic carbonate platform facies, and host the bauxite deposits of Seydisehir-Akseki and Ayranci.

During the Senonian subduction, large-scale obduction created ophiolite nappes, which are part of the major ophiolite belt along the tectonic contact of the Arabian plate with the Tethys orogene (Bozkurt & Oberhänsli, 2001; Gorur & Tuysuz, 2001).

Following the terminal closure of the sutures in the late Eocene – early Miocene, internal deformation, crustal shortening and nappe tectonics did continue. Crustal consolidation and melting resulted in widespread andesitic to basaltic Neogene–Pleistocene volcanism, with volcanoclastic and fluvial-lacustrine basin sediments. In the final stages of the Neogene tectonic evolution, post-collisional intracontinental convergence and faulting created the extensional Aegean graben systems, as well as the two intracontinental Anatolian transform faults, which are still active today as major seismic zones.

Geology of the Central Taurides

The Central Taurides consist of several tectonic units with distinct upper Paleozoic to Tertiary stratigraphy, structure and metamorphism. These units were tectonically superimposed during the Senonian and Lutetian, and most of them extend laterally into the Western and Eastern Taurides (Özgül, 1984).

A single wide platform existed until the end of the Scythian, on which the following units were deposited (from N to S):

- Bozkir Unit (ophiolite nappe)
- Bolkardag Unit
- Aladag Unit
- Geyik Dag Unit
- Antalya Unit
- Alanya Unit

During the Anisian, rifting started to the north and south of the platform. In the south, rifting did not progress far, and the basin was closed before the Rhaetian without forming oceanic crust. A second rifting phase with the formation of oceanic crust occurred between Dogger and Senonian. Rifting and formation of oceanic crust to the north of the platform, characterized by the Bozkir Unit, continued uninterrupted till the Senonian. Compressional tectonics during the Upper Senonian led to the closure of both branches of Tethys. During this event, in the south, the Alanya Unit was emplaced over the Antalya Unit, and in the north, the Bozkir Unit over the Aladag and Bolkardag Units, with the Geyik Dag Unit forming the autochthonous unit at the base.

New rifting during the upper Senonian and the lower Tertiary in the internal parts of the platform generated oceanic crust between the Geyik Dag and Aladag Units. During the Lutetian, this crust was consumed by subduction underneath the Aladag Unit (Dipsiz Göl ophiolite melange). Related to these events, the Aladag and Bolkardag Units moved tectonically to the south, carrying on their back the Bozkir Unit. The Aladag Unit continued its nappe movement over the Antalya and Alanya Units in the south. Upper Lutetian – upper Eocene and Miocene are characterized by post-tectonic transgressive series. The tectonic structure is summarized schematically in Text-Fig. 2.

The characteristic stratigraphic features of the individual tectonic units are as follows:

The autochthonous Geyik Dag Unit at the base consists of platform-type sediments, starting with lower Paleozoic (Cambrian and Ordovician) dolomites, limestones, and shales, overlain by turbiditic clastics, followed by a transgressive Mesozoic – lower Tertiary series, mostly platform-type carbonates. The transgression at the base of the thick, epicontinental Mesozoic carbonate sequences starts in the various areas at different times during the Triassic or Jurassic. Upper Triassic and lower Liassic are characterized by thick intercalations of terrestrial clastics, and the Jurassic–Cretaceous by neritic and pelagic carbonates.

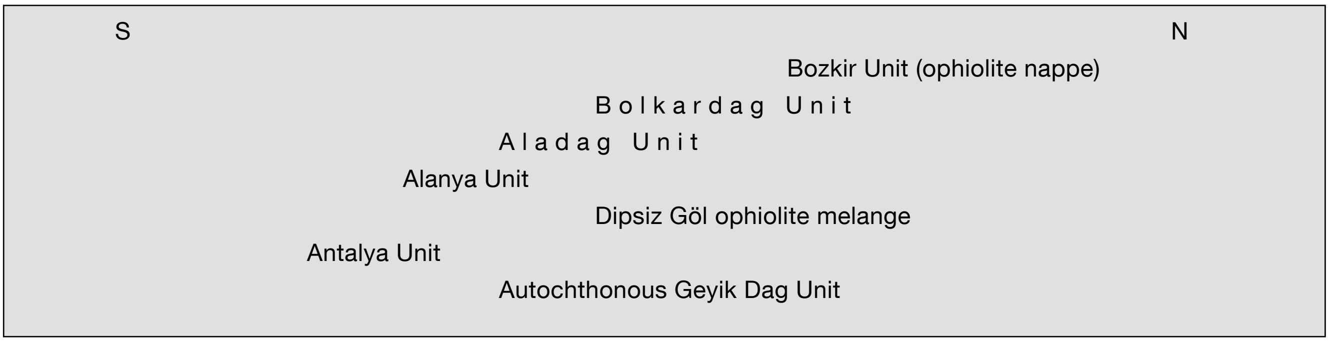
A regional uplift of the platform in the Cenomanian–Maestrichtian resulted in a stratigraphic break. The major bauxite horizons of Seydisehir-Akseki were deposited in a karst relief on this unconformity. They are overlain by Maestrichtian biostromal limestones, topped by Eocene flysch.

The allochthonous Aladag Unit consists of upper Devonian to upper Cretaceous shelf-type clastics and carbonates, and forms a flat lying nappe over the Lutetian flysch of the Geyik Dag Unit. It has no known bauxite potential.

The Bolkardag Unit forms a rootless nappe over the Lutetian flysch of the Geyik Dag Unit, and comprises Devonian to upper Cretaceous shelf-type clastics and carbonates, which underwent occasionally green-schist facies metamorphism of vertically and laterally varying metamorphic grade.

The sequence starts with Devonian schists and marbles, overlain by lower–middle Carboniferous shale, limestone and quartzite, again unconformably overlain by upper Permian neritic carbonates.

A discordance between upper Permian and Triassic hosts the major bauxite deposits of the Ayranci district. The Triassic starts with limestone, shale and quartzite overlain by upper Triassic reefal limestones. A Liassic basal conglomerate represents the transgressive basis of the Jurassic–Cretaceous neritic carbonate sequence. Turonian biomicrites, indicating the start of deep-sea conditions, overlie



Text-Fig. 2.
Schematic tectonic structure of the Central Taurides.

older series unconformably. The distinguishing feature of this unit are the frequent sedimentary breaks in the Devonian to upper Cretaceous sequence, especially in the Permian, Triassic, Liassic and Cenoman, which contain all numerous bauxite horizons.

The Bozkir Unit forms an ophiolite nappe with pelagic sediments, spilite, pietra verde tuffs, diabase and ultramafics. The entire facies indicates a continental margin depositional environment without bauxite potential.

In the south, the Antalya Unit consists of Cambrian–Ordovician turbiditic sandstones, transgressively overlain by upper Permian algal neritic carbonates. Scythian tidal stromatolithic and oolithic limestones with small bauxite deposits at their base are overlain by variegated limestones and marls with intercalations of radiolarites, shales, volcanics and turbiditic sandstones. Jurassic starts with reefal carbonates, and Dogger to Senonian is represented by radiolarites and pelagic biomicrites.

The Alanya Unit consists of three metamorphic nappes without bauxite potential.

The thin but laterally continuous Dipsiz Göl ophiolite melange of ultramafites and pillow lavas with intercalated Cretaceous – lower Eocene pelagic limestones and shales overlies the Lutetian flysch of the Geyik Dag Unit and underlies the Aladag Unit. It has no known bauxite potential.

General Genetic Concept

Öztürk et al. (2002) analyze the genesis of the Seydisehir deposits in detail, including the overall tectonic and sedimentary environment for the general genesis of the Cretaceous Turkish bauxite deposits. Similar genetic concepts are possibly applicable to a certain extent to the other Turkish karst bauxites.

The platform limestone sequence which hosts the Seydisehir bauxite deposits developed at a passive oceanic margin. The humid, warm Cretaceous climate led to extensive tropical vegetation with thick, acidic, humic soils. The closure of the Tethys Ocean caused local uplifts of this passive margin, with karstification and bauxite formation in topographic lows. Al, Fe- and Ti-oxides, and clays from the incipient bauxite or bauxitic soil were transported as detrital phases or in suspension, and accumulated in fault-controlled depressions or sinkholes. Marine transgressions into the foreland basin and nappe emplacement during the latest Cretaceous followed the bauxite deposition.

The sources of Al, Fe, and Ti in the Cretaceous bauxites were probably parent alumo-silicate host rocks, most likely argillaceous sedimentary rocks or mica-rich granites and/or gneiss. Characteristic textures, such as intercalations of bauxite and calcareous conglomerate, reworked bauxitic material, or lenses of graded beds in the bauxites indicate the abrupt accumulation of the bauxitic material. Such high-energy, mass-flow depositional conditions were probably triggered by tectonic activities, which is indicated by the predominant accumulation in fault-bounded depressions, and by the abrupt nature of the deposition.

Öztürk et al. (2002) propose three stages for the genesis of the Cretaceous bauxites of Seydisehir.

- During stage 1, Al, Fe, and Ti were dissolved from the alumo-silicate parent rocks under extremely acidic weathering conditions. This process resulted in the accumulation of a bauxitic soil (bauxite minerals, Fe and Ti oxides, and clay minerals) on the limestone surface.
- In stage 2, the bauxitic soils were transported by mass movements to fault-controlled basins and karst depressions, where they accumulated as relatively thick bauxite ores by clastic deposition. The erosion of the bauxitic soils was promoted by rapid uplift due to active tectonics.
- During stage 3, the ore was upgraded by in situ leaching and desilicification under the conditions of a well-developed karst drainage system. According to the mineral paragenesis, the redox conditions fluctuated several times during deposition and diagenesis.

A paleogeographic reconstruction of the Tethys Ocean in the Taurus mountains during the Santonian indicates a passive-margin setting. The shallow-marine platform environment was presumably marked by fault-controlled depressions and highs. Within this passive margin, the Al, Fe, Ti, and Mn oxides were fractionated and mobilized by tropical weathering from thick acidic soils. Mn and Si were transported to the sea, while Al hydroxides and Fe were mostly trapped on land, primarily as insoluble hydroxides.

The relatively rapid sea-level changes were probably related to tectonic activities, since the oxygen isotopes of the host limestones indicate that the paleoclimates did apparently not vary much from pre-bauxite to post-bauxite time (Öztürk et al., 2002). A regression exposing the limestone surface probably resulted from faulting related to the closure of Tethys with local uplift of the passive margin, which caused karstification and bauxite accumulation on the limestone surface. Subsequent transgressions submerged the Seydisehir bauxite deposits, followed by nappe emplacement and the deposition of bioclastic limestones on the nappe ramp during the latest Cretaceous.

Throughout the entire Alpine region, bauxite deposits in passive-margin sequences are quite common. According to the model of Öztürk et al. (2002), bauxite deposition and the fractionation of Mn, Fe, and Al, plus the separation of Fe and Mn occurred primarily on land, when the tropical climate and extensive vegetation during the Cenomanian and Santonian caused thick acidic humic soils. Acid rain from volcanic activities could have affected the pH value of the soils, but no volcanics were observed in the stratigraphic succession with the bauxite deposits. Öztürk et al. (2002) favour therefore a dominant climatic control for the acidification of the soil, and cite carbon and sulphur isotope compositions as key evidence for the importance of organic matter and bacterial processes for the acidic environments and for mobilizing Al.

The regional Alpine paleo-environments, which promoted the formation of the bauxite deposits probably reflect global geological processes. Extensive oceanic volcanism and tectonics, high sea-level stands, and widespread oceanic anoxia characterized the Late Cretaceous. Globally extensive anoxia may also have contributed to the reducing conditions during transgression and early diagenesis.

This genetic concept of Öztürk et al. (2002) concurs with the genetic concepts of Petrascheck (1989) for some southern European allochthonous karst-type bauxite deposits, and with observations of the author, however, without pretension that these concepts are valid everywhere. However, the consideration of these paleogeographic and genetic factors can be of valuable assistance when deciding on exploration strategies, or assessing deposits.

According to Petrascheck (1989), several Mediterranean karst bauxites reveal common features of fluvial transport and sedimentation. They are in general allochthonous, originate from neighbouring silicate rocks, and their trace element spectra reflect the petrology of the rocks of origin. The bauxites are sometimes transported over considerable distances. Petrascheck (1989) mentions in certain cases transports over 30 km, which occurred either as slow fluviatile transport, mainly as suspended mud, but there is also evidence for transport in rapidly flowing water. Petrascheck (1989) considers it unlikely, that the sediment load of the rivers was trapped in the depressions and sinkholes of a karst plateau. Instead, sporadic marine fossils in the bauxites point to coastal environments for the deposition of bauxitic muds in depressions of slightly karstified coastal plains in lagoonal or estuarine environments, i.e. embryonic karsts. Later tectonic uplift and post-bauxitic karstification created mature karsts.

The depth of these sinkholes and depressions, and therefore the thickness of the ore bodies was controlled by the groundwater table during the time of deposition. The ore bodies are therefore thicker in the more elevated parts, than near the former seashore, and their thickness increases with the distance from the former shoreline. The horizontal shape of the ore bodies is influenced by the direction of drainage and by the structural control of the karst features.

Petrascheck (1989) observed also a relationship between the transport distance and the quality of the bauxites. In several bauxite districts, the Al_2O_3 content decreases and the SiO_2 content increases with the direction of the flow of the river system; the corresponding decrease of the Eh/pH ratio favoured the precipitation of diaspore.

Description of Selected Turkish Bauxite Deposits

Seydisehir-Akseki Boehmitic Bauxite Deposits

The economically most important Turkish bauxite deposits occur at Seydisehir-Akseki in the central Taurus range, where the Mortas and Dogankuzu open pits are the largest Turkish bauxite mines. They exploit karst-related unconformity-type deposits in Upper Cretaceous limestone. The detailed analysis of these two major deposits by Öztürk et al. (2002) is by analogy also applicable to the nearby Akseki deposits, which occur in the same stratigraphic and tectonic setting.

The deposits are hosted by the Geyik Dag Unit, which consists here of Paleozoic phyllite and greywacke, unconformably overlain by Triassic and Jurassic carbonates. The Cretaceous includes a carbonate sequence with a thickness of more than 1,000 m. A regional uplift of the platform in the Cenoman–Maestrichtian resulted in a stratigraphic unconformity, where the bauxites were deposited in a karst relief. They are overlain by Maestrichtian biostromal limestones, and Palaeocene to Eocene limestones and sandstones.

The autochthonous unit is overlain by allochthonous serpentinized ultramafics, and Permian limestone and dolomites, probably obducted on the autochthonous basement during the Oligocene. Post-tectonic Miocene and Pliocene sediments terminate the stratigraphic sequence.

Detailed exploration of the Seydisehir deposits by ETI Aluminium established a reserve of boehmitic bauxite of 25.8 mill. t at 57–58 % Al_2O_3, of which 6 mill. tons have already been mined (Öztürk et al., 2002). The Akseki deposits contain also boehmitic bauxite with a total resource of 17.5 mill. t at 47–66 % Al_2O_3 (Yigit, 2009), but with smaller individual ore bodies. This could be caused by deeper erosional levels for the Akseki deposits, or possibly by the fact, that the larger Seydisehir ore bodies were further inland from the Cretaceous seashore, and had therefore deeper hydrographical levels during bauxite deposition.

The bauxite consists mostly of boehmite and hematite, with minor anatase and smectite. Kaolinite fills well-developed joints in the bauxite. The structure is pisolitic, with colloform hematite, and boehmite pisolithes and ooids of widely variable sizes. High-grade bauxite consists of a boehmite groundmass with disseminated and colloform hematite grains. The average quality of the bauxites is in the following ranges:

Mineralogy:	Boehmite bauxite (alumina minerals: + 90 % boehmite)
Al_2O_3:	typically around 55–57 %
Total SiO_2:	typically 5–6 %
Fe_2O_3:	typical in the range of 15–20 %
TiO_2:	2–3 %
Loss on ignition:	12–15 %

Ayranci Diasporite Bauxite Deposits

The Ayranci deposits occur in the Central Taurus, which consists in this region of the Bozkir, Aladag and Bolkardag Units (Demirtasli et al., 1984). The Bolkar Group of the Bolkardag Unit is a thick limestone sequence with intercalated shales and dolomites, and hosts the main bauxite deposits. It consists of the following four formations with generally conformable contacts:

- Dedeköy Formation (Permian): Thick-bedded, partly dolomitic recrystallized limestones with intercalated micaceous slates, deposited under stable shelf conditions and with an epizonal metamorphic overprint. An unconformity at the top of this formation caused a structurally controlled karst relief, where the major bauxite ore bodies were deposited.
- Gerdekesyayla Formation (Lower–Middle Triassic): Thin-bedded shales and limestones grading upwards into thick-bedded dolomitic limestones with shale and marl intercalations, deposited on an open marine shelf.
- Berendi Formation (Upper Triassic): Thick carbonate sequence with basal thick-bedded dolomites grading into medium to thick bedded limestones with bauxite pockets, indicative of a shallow marine stable carbonate platform.
- Üctepler Formation (Jurassic–Cretaceous): Medium-bedded, partly oolitic and dolomitic limestones, in

which bauxite pockets are common; overlain by thick bedded dolomites, reefal limestones and pelagic limestones, deposited on a shallow marine stable carbonate shelf, which changed into an open marine and deep pelagic sedimentary environment.

The bauxites indicate local subaerial exposures during sedimentation, and occur as numerous elongated, lenticular bodies of varying dimensions in a paleokarst on Permian limestones with structurally controlled sub-parallel alignments (Dedeköy Formation). Numerous limestone intercalations and small ridges in the massive bauxite reflect the old karst relief. The structural control was apparently rejuvenated during subsequent tectonic deformation phases, leading to an overprint of the bauxite-bearing paleokarst by sub-recent karst development. White, micritic limestones, partly cellular and with unclear fossil relics overlie the bauxite unconformably.

The bauxite forms a hard, massive, compact ore of fine grained diaspore with mm-sized, dark, lenticular to subrounded pisolithic grains, occasionally with a fine grained bauxite core of hematite or Ti-minerals. Specularitic hematite coats occasionally joints. The mineralogy comprises diaspore and hematite with minor goethite. Kaolinite and quartz are the silica minerals. TiO_2 occurs as anatase. Birön & Atak (1986) state a total resource of 10 mill. t at 53 % Al_2O_3.

The quality distribution in the individual bauxite lenses is characterized by internal primary structures, and by thin secondary near-surface zones of supergene enrichment, where SiO_2 was leached. In terms of grade – grain size distribution, SiO_2 tends to be enriched in general in the fine fractions. The average quality of the bauxite is in the following order of magnitude:

Mineralogy:	Diaspore bauxite (alumina minerals: + 90 % diaspore)
Al_2O_3:	typically around 53 %
Total SiO_2:	typically 6–7 %
Fe_2O_3:	15–30 %
TiO_2:	2–5 %
Loss on ignition	10–12 %

Islahiye Ferrous Bauxite Deposits

The ferrous bauxite deposits of Islahiye occur in the Amanos range, which consists of an ophiolite nappe thrust onto the northern margin of the Arabian platform during the Senonian subduction phase.

Yalcin (1980) describes the complex regional geology. The Upper Cretaceous carbonate series with the bauxite deposits transgresses on Paleozoic epizonal metamorphic basement of phyllites, schists, quartzites and gneiss. Subduction tectonics caused inverse overthrust structures between crystalline basement and the carbonate series as well as the tectonic intercalation of serpentinites and ophiolites in the Cretaceous limestones. The limestone-ophiolite complex is truncated towards east by graben structures, which are the northernmost extension of the major East African – Red Sea – Jordan – Orontes rift system, and are marked by numerous young basalt cones and flows in the graben between the rift escarpments.

The Cretaceous bauxite forms distinct horizons of elongated belts and karstic bauxite pockets, controlled by a structural alignment conforming to the regional geological trend. Marine limestones overlie the bauxite unconformably. The complex tectonic interaction between the ophiolites, which could also be possible source rocks as indicated by rare occurrences of rounded serpentinite fragments in the bauxite, and the carbonate series may account for the complex chemical composition of the bauxites, especially for the elevated TiO_2 contents.

The Islahiye bauxites are silicate bauxites with massive and pisolithic ore and complex mineralogy. They consist of diaspore with subordinate gibbsite and boehmite. TiO_2 occurs as anatase, the silica is contained in kaolinite and illite. Although the bauxite bodies appear homogeneous, their internal structures are characterized by relatively strong quality fluctuations over comparatively short distances.

Statements on the average range of the bauxite quality have to take into account that only a part of the deposit is explored systematically, and that the assay data fluctuate strongly. Yigit (2009) reports a mineral resource of 96 mill. t at 41 % Al_2O_3, while Birön & Atak (1986) refer to 120 mill. t at 46–58 % Al_2O_3.

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