International Journal of Physical Sciences Vol. 7(15), pp. 2387 - 2397, 9 April, 2012
Available online at http://www.academicjournals.org/IJPS
DOI: 10.5897/IJPS12.092
ISSN 1992 - 1950 ©2012 Academic Journals

Full Length Research Paper

Evaluation of Turkish black amber: A case study of Oltu (Erzurum), NE Turkey

Ekrem Kalkan[1]*, Özgür Bilici[1] and Hasan Kolaylı[2]

[1]Department of Geological Engineering, Oltu Earth Sciences Faculty, Ataturk University, 25400 Oltu-Erzurum, Turkey.
[2]Department of Geological Engineering, Engineering Faculty, Karadeniz Technical University, 61000 Trabzon, Turkey.

Accepted 23 March, 2012

Turkish black amber named Oltutaşi in Turkish is one of the best examples of semi-precious stone to be found in the world. It is mainly extracted in the county of Oltu (Erzurum) and surrounding mountains, NE Turkey since the 18th century. At the present time, it is known as ornamental stone and its rosary is very famous worldwide. However, there is no modern review of geological properties of the Oltutaşi and Oltutaşi-bearing deposits. This paper filling this gap presents the results of original research on the subject. The Oltutaşi-bearing deposit with Jurassic-Cretaceous is a flych-character sequence, including limestone, sandstone interbedded with volcanic, sandstone, marl and claystone levels. The Oltutaşi is seen as a form of lenses with 0.2 to 75 mm in thick within the Oltutaşi-bearing geological material represented by pebble-sandstone-siltstone alternation, including sandy-claystone and marl levels. These lenses present the folded and faulted structures in parallel with the main rocks due to the tectonic deformation affecting the region. It is seen from microphotographs that Oltutaşi dominantly consists of carbon and it includes resinite and maceral such as fusinite and semifusinite. Also, it is possible to observe that euhedral pyrite and hematite minerals generally finely disseminated the Oltutaşi organic matter.

Key words: Oltu, Oltutaşi, Turkish black amber, Jurassic-Cretaceous flysch, semi-precious stone.

INTRODUCTION

Amber, a fossilized natural product, is an organic material of considerably insert with respect to various scientific disciplines and art (Buchberger et al., 1997). It is an organic (amorphous) matter that hardens when exposed to air. As understood from the literature, the earliest amber formation occurred in the Carboniferous period *ca* 300 million years, and became abundant in the late Cretaceous period *ca* 80 million years ago. Amber is known to preserve organism's morphologically and genetically intact (Hamamoto and Horikoshi, 1994). It is usually indurate, massive and resistant to organic solvents. Amber can be transparent, but more frequently it is translucent with yellow, reddish, brown, blue-brown or black color.These characteristics are the consequence of diagenetic changes that operate in copal after burial in the sedimentary pile, sometimes at depths over 1000 m, where it is subjected to elevated temperature and pressure. Under these conditions and several millions of years, copal is naturally cooked and transformed into amber (Langenheim, 1990; Iturralde-Vinent, 2001; Knight et al., 2010).

Around the world, a wide variety of different types of amber can be found, including succinite, gedanite and beckerite from the Baltic area, burmite from Burma, simetite from Sicily and Roumanite from Rumania as some of the most important amber. Furthermore, ambers from Mexico, Lebanon, Australia, New Zealand and the Dominican Republic are the second most important amber from a commercial point of view, today known to be demonstrating the omnipresence of amber (Grimaldi, 1996; Carlsen et al., 1997). Although, a specific time interval has not been established for the amber forming process, majority of amber is found within Cretaceous and tertiary sedimentary rocks. Cretaceous amber with

*Corresponding author. E-mail: ekalkan@atauni.edu.tr. Tel: +90 442 816 62 66. Fax: +90 442 816 33 32.

common organic inclusions has been found at various localities, including sites in the Valanginian-Aptian Levantine amber belt of Lebanon (Nissenbaum and Horowitz, 1992), Jordan (Poinar and Milki, 2001), Israel (Azar, 2007), Northern Spain (Alonso et al., 2000; Penalver et al., 2007), Western France (Nel et al., 2004; Girard et al., 2008), Myanmar (Grimaldi et al., 2002; Cruickshank and Ko, 2003), South Africa (Gomez et al., 2002), Western Canada (Penney and Selden, 2006) and the U.S. (Franks, 1980; Grimaldi et al., 2000; Knight et al., 2010).

Single ambers are different in their appearance as well as in density and hardness. Therefore, the amber colors range from almost pure white through yellow and red to virtually black. The differences in color are partly associated with the presence of minor inclusions filled with air, water or sap (Carlsen et al., 1997). The amber is usually transported by water flows to the final sedimentological deposits. During transport, the mixing of resins produced by different trees at different altitudes can occur. For this reason, paleoecological of forests ecosystems based on amber inclusions need to be especially accurate (Schlee, 1990; Poinar and Poinar, 1999; Poinar, 1991; Lee and Langenheim, 1975; Tyson, 1995; Iturralde-Vinent, 2001; Cruickshank and Ko, 2003; Martinez-Delclos et al., 2004; Delclos et al., 2007).

The presence of amber is associated with lignite and this is known from Cuba (Miocene lignite), Haiti (Miocene lignite and traces of amber), the Dominican Republic (Miocene lignite and amber in exploitable quantities), Puerto Rico (Oligocene and Miocene lignite and traces of amber) and Jamaica (Maastrichtian-Paleocene amber). Also, it is indicated that amber is contained in lignite-rich sediments (Eberle et al., 1982; Anderson and Crelling, 1995; Penalver et al., 2007; Iturralde-Vinent, 2001; Pastorelli, 2009).

The Turkish amber is known as “Oltustone”, “Erzurum Stone”, “Black Amber”, “Gagat”, “Jayet” and “Jet” in the literature (Ethem, 1990). It is called “Oltutaşi”, “Erzurum Taşı”, “Kara Kehribar” and "Sengi Musa” in the Turkish language. The Oltutaşi is a geological material and it is not considered a true mineral, but rather a mineraloid derived from decaying wood under extreme pressure and thus organic. It is a very dense mineral-like substance of the nature of coal that does not demonstrate crystalline. It generally comes in black, but can also be velvet-black, blackish, gray or greenish. The softness of Oltutaşi when excavated is the most interesting characteristic. It begins to harden when exposed to the air. For this reason, it can be carved very easily. It attracts, by way of static electricity, light substances like dust when rubbed. Oltutaşi burns bursting in flames and leaves ash behind. The structure of Oltutaşi, which is remarkably like the wood, can be seen under magnification (Ethem, 1990; Parlak, 2001; Karayiğit, 2007; Hatipoğlu et al., 2012).

Although, the Oltutaşi and its circumstantial evidence are observed in most of the Oltu and Olur (Erzurum) villages, it is heavily extracted from the geological unit in the Yasak Mountain and its surrounding area (Dutlu village of Oltu), Northern Oltu. Its extracting is carried out by non-technological methods in the underground galleries. It is processed by local artisans and it is converted into a valuable products. There are some scientific and advertising papers published on the Oltutaşi (Lahn, 1939; Zengin, 1956; Çiftçi et al., 2002, 2004; Karayiğit, 2007; Bilgin et al., 2011; Hatipoğlu et al., 2012)

The X-ray powder diffraction (XRD) analysis using Philips PW 1010/80 diffractometer with graphite-filtered CuKα radiation was conducted to determine the physical, chemical and mineralogical properties of Oltutaşi and Oltutaşi-bearing deposits. The Oltu Taşı samples were cut in appropriate size, ground and polished for polished section analysis. Prepared sections were examined in the overhead lighting Nikon ECLIPSE E400 POL ore microscopy and then mineral assemblage; other components were identified and photographed.

GEOLOGY

The Oltutaşi-bearing deposits lie at approximately 130 km Erzurum, NE Turkey (Figure 1). These deposits are located in the eastern part of Pontide belt, which forms the basement, occupies a broad belt parallel to the coast of the Black Sea. The largest and uppermost part of the Pontide sequence is the Olur-Tortum zone which is made up of a series of arc-related volcano-sedimentary beds of late Cretaceous-Eocene age formed during a long period of northward subduction. This may be underlain by a Mesozoic volcano-sedimentary unit related to older subduction events, or by a Late Cretaceous ophiolitic melange termed the Eastern Anatolian Accretionary Complex (Yılmaz and Boztuğ, 1996; Keskin et al., 1998; Konak et al., 2001; Boztuğ et al., 2004).

The Permo-Carboniferous, Jurassic-Cretaceous, Tertiary and Quaternary-aged geological units outcrop in this region (Figure 2). The Oltutaşi lenses are included in the Jurassic-Cretaceous geological deposits. In this region, the early studies were conducted by Erentöz (1954), Gattinger (1955), Baykal (1950) and Nebert (1964) on the main stratigraphy, lithology and tectonic properties of the region. There are many detailed geological studies performed by Bulut et al. (1984), Koçyiğit and Roja, (1984), Yılmaz (1985), Bozkuş (1991), Dönmez and Işık (1999), Konak et al. (2001), Kalkan (2003), Kalkan and Bayraktutan (2008) and Konak and Hakyemez (2008) in the region.

Sedimentary sequence including Oltutaşi lenses consist of sandstone and siltstone alternation, including pebble layers and volcanic interlayers in some places. This sequence named as Olurdere formation (Yılmaz, 1985) is lateral transitive with Soğukçam formation (Konak and Hakyemez, 2008) consisting of micritic limestone and clayey micritic limestone including chert nodules

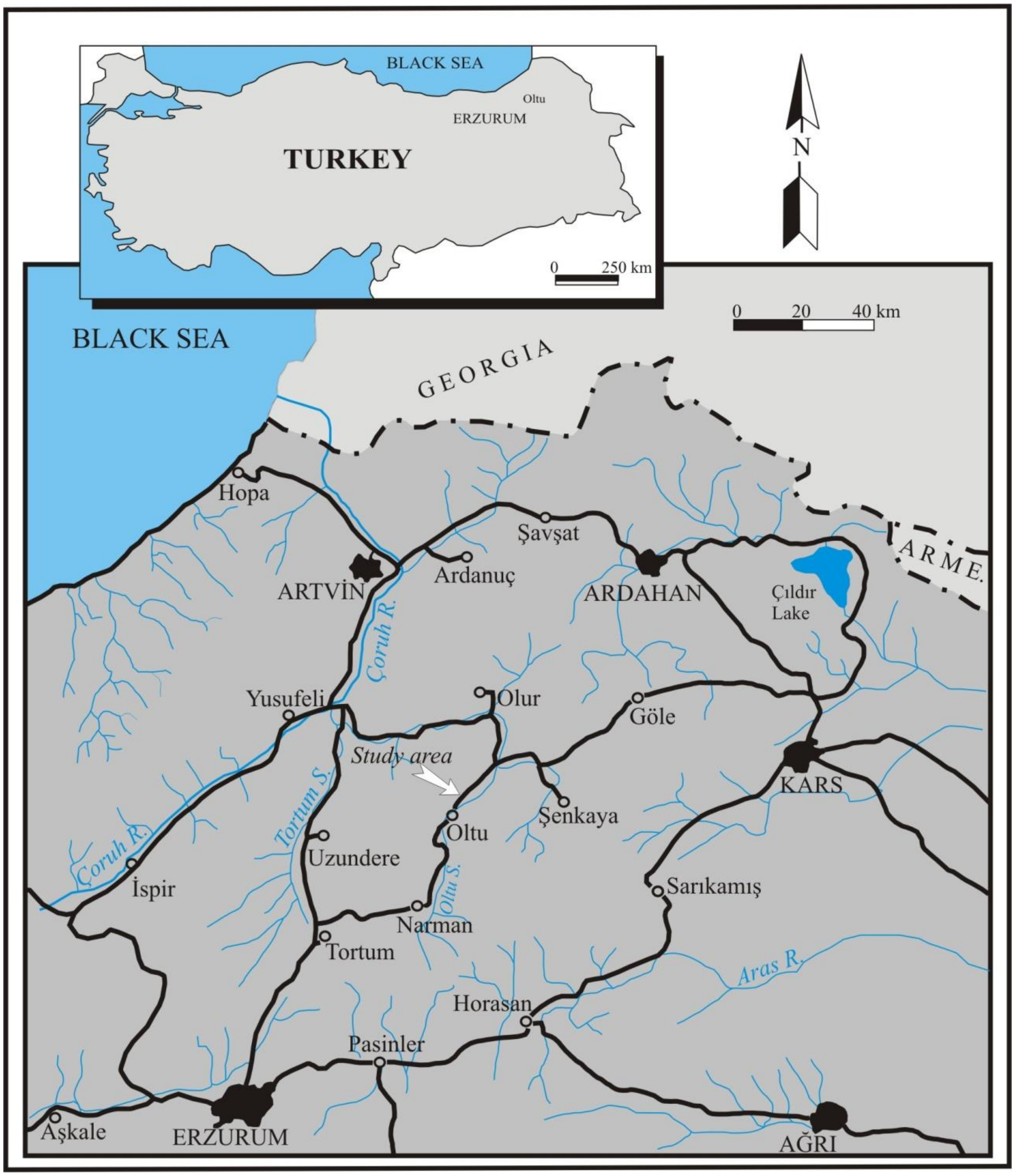

Figure 1. Location map of the study area.

and bands at the upper levels.

This formation begins in general clastic sediments with coarse particles in the southern slope of Dutlu Mountain (Oltu, Erzurum). In this region, pelagic pebbles with lenticular geometry that are poorly sorted are observed in the lower levels of sequence (Konak et al., 2001). It continuous with pebble-sandstone-siltstone alternation to upward and then it changes to alternation of sandstone-siltstone with thin layer at the upper side. The sandstone-siltstone alternation is Oltutaşi-bearing deposits. The Oltutaşi operating galleries is opened within this sandstone-siltstone alternation on the pebbles (Yılmaz, 1985; Bozkuş, 1991; Dönmez and Işık, 1999; Konak et al., 2001). The black amber (Oltu taşı)-bearing geological units have sedimentary character and Cretaceous age, and also, these units have similar properties with other amber-bearing sediments with Cretaceous age and other ages mentioned by some researchers (Langenheim, 1969; Brouwer and Brouwer, 1982; Redmond, 1982; Van den Bold, 1988; Iturralde-Vinent and MacPhee, 1996;

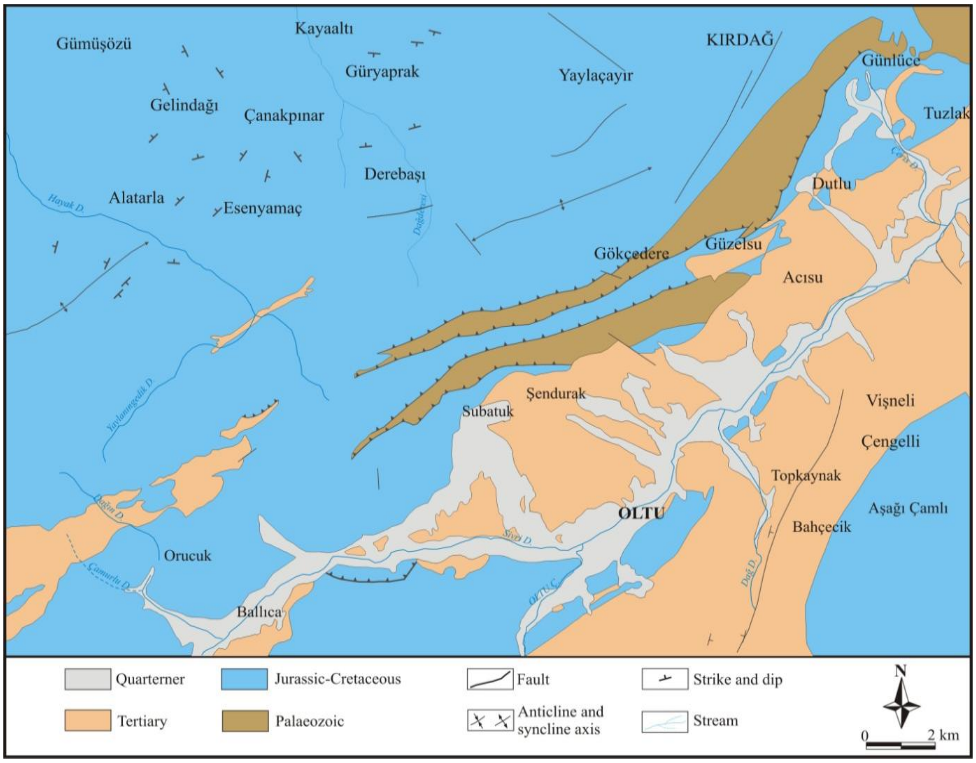

Figure 2. Simplified geological map of the study area.

Iturralde-Vinent and Harstein, 1998; Iturralde-Vinent, 2001; Otto and Wilde, 2001; Cruickshank and Ko, 2003; Pastorelli, 2009).

This formation includes andesitic-basaltic lava in the some levels. Its fine grained deposits include macro fossils, such as, ammonite, pelesipod and gastropod fossils and its micro fauna consists of *Protopeneroplis trochangulata* Septfontaine, *Conicospirillina basiliensis* Mohler, *Trocholina alpina* (Leupold), *Protopeneroplis* specie, *Conicospirillina* specie, *Trocholina* specie, *Protoglobigerina* specie, Haplophragmium specie, *Calpionella* specie, *Ammobaculites* specie, *Nautiloculina* specie, *Cuneolina* specie, *Spirillina* specie., *Neotrocholina* specie, *Reophax* specie and *Feurtillina* specie. The Olurdere formation is aged as Oxfordian-Berriasien according to its micro and macro fauna (Konak et al., 2001; Konak and Hakyemez, 2008).

TECTONIC

The Eastern Anatolia region, which is one of the extensive regions of high elevation along the Alpine Himalayan mountain system (Şengör et al., 2008) is located over the Africa-Eurasia collision zone between the Arabian foreland in the Southwest and the Lesser Caucasus in the Northeast. It was produced by a succession of collisions between the Arabian and Eurasian continents during the late Miocene (Şengör and Yılmaz, 1981; Dewey et al., 1986) and rapid uplift of the region due to the break-off of a north-bound subducted slab of the Northern Neo-Tethys ocean crust (Keskin, 2003; Şengör et al., 2003; Şengör et al., 2008).

Previous research has shown that the compressional tectonic regime created by the collision between the Arabian and Eurasian plates along the Bitlis suture zone has resulted in extensive crustal shortening (Şengör and Kidd, 1979; Şengör and Yılmaz, 1981; Dewey et al., 1986). Consequently, the terrain has been uplifted and continental crust almost doubled in thickness of 45 to 50 km (Canıtez and Toksöz, 1980). Diffuse, shallow seismicity in the region indicates that it is still being actively deformed and thickened (Şengör and Kidd, 1979; Pearce et al., 1990) and hence that the collision is still in progress in Eastern Anatolia. The pre-collisional and collisional tectonic framework of the region is presented and discussed in Şengör and Kidd (1979), Şengör and Yılmaz (1981), Şengör et al. (1985), Dewey et al. (1986), Pearce et al. (1990) and Keskin et al. (1998).

The study area is located in the Northeastern Anatolian Region between the Pontides belt (North Anatolian Mountain Ranges) in the North and the Anatolides belt (Inner Anatolian Mountain Ranges). The tectonic movements become effective on the forming of Northeastern Anatolian Region and this region is under control of compressive stress with North-South direction, since the

Cretaceous (Şengör et al., 1985; Koçyiğit et al., 1985). This stress is covered by right and left strike-slip faults in the Eurasian plate after the continent-continent collusion between Eurasia and Arabia plates during the upper Miocene-lower Pliocene (Koçyiğit and Rojay, 1984). In this region, large-angle trust faults with East-West direction developed under the control of this compressive stress (Şengör and Yılmaz, 1981). There are also some normal faults with North-South direction cutting the trust faults and fold structures (Figure 2).

In this region, many important curved-overlap structures and strike-slip faults began flourish during the upper Pliocene-lower Eocene. This geological period was the most active period in terms of regional tectonics. In this period, the tectonic regime caused some significant changes, such as strice-slip faults with Northeast-Southwest direction. In this process, the folds with axis departure in the same direction of tectonic lines changed to overlap structures by overthrowing or pushing in some places (Figure 2). It is through the dasitic intrusions settled in the anticlinal core as laccolith and lappolith are the same age (Konak and Hakyemez, 2008).

GEOLOGIC OCCURRENCE

The Oltutaşi lies in the sedimentary sequence of the Jurassic-Cretaceous called Olurdere formation (Yılmaz, 1985). The formation composes of conglomerate, volcanic levels and sandstone-siltstone alternation. The sandstone-siltstone alternation characteristically, includes the Oltutaşi and lignite lenses (Konak and Hakyemez, 2008).

Amber is deposited in the marginal marine environment. It floats in saltwater and becomes concentrated in estuarine or marine deposits, moved some distance from the original site due to its slightly over 1 of specific gravity (Langenheim, 1969; Iturralde-Vinent, 2001; Pastorelli, 2009). The fossil resin becomes incorporated into sediments and soils, which over millions of years change into rock, such as, shale and sandstone. Therefore, amber is formed as a result of the fossilization of resin that takes millions of years and involves a progressive oxidation and polymerization of the original organic compounds and oxygenated hydrocarbons. The composition, color and other physical properties of amber all vary according to age, conditions of burial and type of tree that produced the resin (Buchberger et al., 1997; Knight et al., 2010).

Oltutaşi and lignite lenses are usually found as local concentrations in particular horizons. This implies that the factor controlling the concentration of wood and copal fragments operates during sedimentation-combination of paleo-relief and transport. The woods of resin-rich trees and resin-free trees and resin may be transported and deposited in quiet water sediments that formed the bottom of the lagoonal and coastal swamp environments (Brouwer and Brouwer, 1982; Redmond, 1982; Eberle et al., 1982; Iturralde-Vinent, 2001). Wood and resin are buried under the sediment, while the resin and resin-rich woods become amber; the resin-free woods become lignite. When the copious resin producing trees and appropriate burial conditions are satisfied, amber is preserved in sedimentary clay, shale and sandstones associated with layers of lignite. In this area, Oltutaşi and lignite are found together and there are some Oltutaşi and lignite lenses seen as flattened wood structures. Eberle et al. (1982) indicated that amber is always contained in lignite-rich sandstone beds or in lignite seams and that considerable amounts have been mined from a few tens of meters above prominent onglomeratic horizons.

In literature, it was distinguished that there are several type of copal from different geographic regions and trees, such as Zanzibar copal from East Africa was possibly produced by the *Trachylobium verrucasum* (*Hymenaea verrucosa*), Kauri copal from New Zealand was produced by the Kauri pine, *Agathis australis,* Sierra Leone and Congo copal are both from a leguminous tree, *Copaifera guibourthiana,* Manila copal found in Indonesia and Philippines was produced by trees in the genus *Agathis*, Dammar resin from Malaya and Sumatra was produced by dipterocarpaceous trees and Colombian and Brazilian copal was produced by various tropical trees, such as *Hymenaea courbaril* or *Hymenae protea* (Rice, 1999).

The Oltutaşi and lignite are usually observed as lenses within the layers of Oltutaşi-bearing deposits (Figure 3a). There are differences between physical properties of Oltutaşi and lignite. The Oltutaşi exhibits massive structure and matt appearance (Figure 3b), while the lignite bodies are compact and deep black with a metallic shine (Figure 3c). On the other hand, the Oltutaşi is soft when first extracted and becomes harder as it is carved by contacting with the air, but the lignite is hard when first extracted then breaks to pieces (Figure 3c). It is possible to find Oltutaşi as flattened wood pieces within Oltutaşi-bearing deposits. The cross section and top view of this flattened wood structure are illustrated in Figure 4a and b, respectively.

PHYSICAL AND CHEMICAL PROPERTIES

The physical properties of amber also have a high variability depending on the provenance and the typology; while on the other hand, the elemental analysis is rather constant and does not easily allow distinguishing material coming from different deposits (Grimaldi, 1996; Ross, 1998; Rice, 1999; Pastorelli, 2009). The physical and chemical properties of Oltutaşi are as shown in the Table 1. Although, Oltutaşi is soft when first exploited, and becomes harder as it is carved by contacting with the air. It gets glossy as long as it is used. Its color is usually black, exceptionally brown; it burns when contacted with a flame, heavier than plastic, lighter than glass. On sandpaper, it draws a brown line, polyester or plastic draws a white line. When rubbed, the Oltutaşi attracts, by

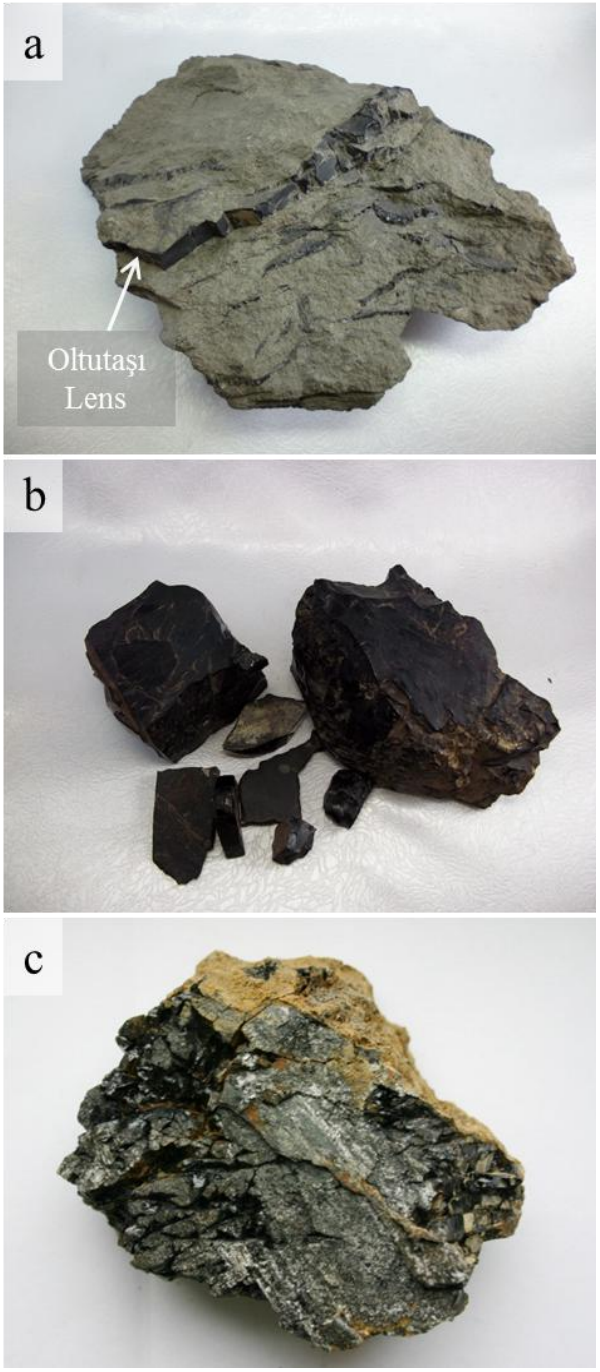

Figure 3. Some photographs; (a) Oltutaşi-bearing deposit sample including Oltutaşi lens, (b) Oltutaşi particles and (c) Lignite particle.

way of static electricity, light substances, such as, dust (Ethem, 1990; Parlak, 2001; Çiftçi, et al., 2004; Karayiğit, 2007; Hatipoğlu et al., 2012). The Baltik amber has the amorphous structure, hardness of 1.5 to 3 in the Mohs scale, density of 1.023 to 1.125 g/cm^3 and carbon ratio of 67 to 87% (Pastorelli, 2009); these properties are similar to those of Oltutaşi organic matter.

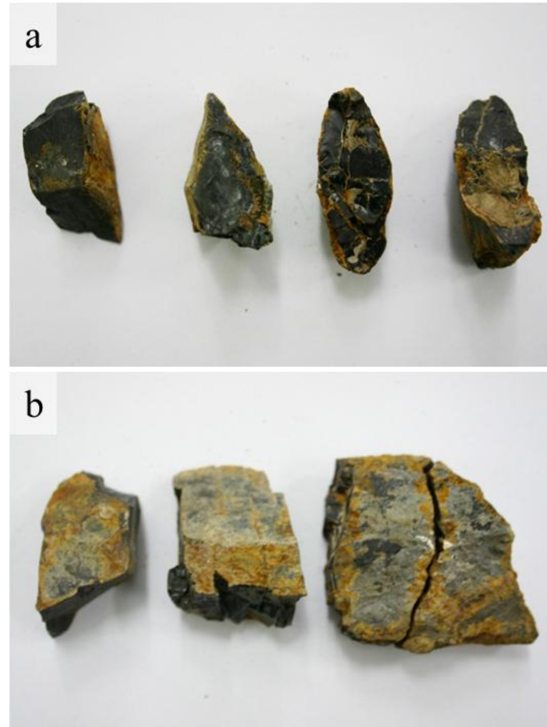

Figure 4. Photographs of Oltutaşi; (a) cross section of Oltutaşi particles looking flattened tree and (b) top view of Oltutaşi particles looking flattened tree.

Table 1. Physical and chemical properties of Oltutaşi.

Components	
Chemical structure	$C_{10}H_{160}$, succunic acid
Crystal system	Amorphous
Hardness	3 mohs
Density (g/cm^3)	1.5
Carbon ratio (%)	78
H_2 (%)	6.72
S (%)	0.9
Ash (%)	0.3
Volatile matter (%)	45.35 (Bochmer), 51.37 (ASTM)
Moisture (%)	2.18
Calorie (K.cal/g)	8064
Specific gravity	1.26

The chemical composition of amber consists of a complex mixture that mainly includes terpenoids and phenols, with minor amounts of alcohols, acids, fats and rarely amino acids (Alekseeva and Samarina, 1966; Urbanski et al., 1984; Mills et al., 1984; Mills and White, 1999). This composition is extremely variable and depends on several factors, such as provenance area, geological history, diagenetic alterations, paleoclimate and paleo-botanic source (Langenheim, 1969; Savkevich,

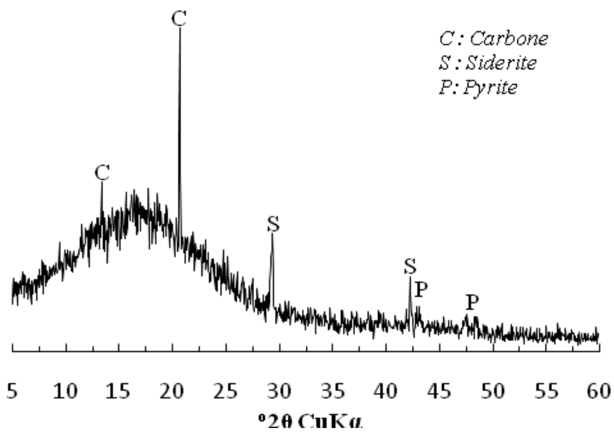

Figure 5. The XRD pattern of Oltutaşi.

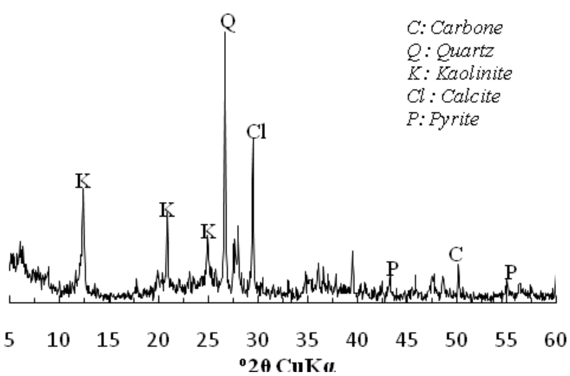

Figure 6. The XRD pattern of Oltutaşi-bearing deposits.

1981). It has amorphous crystal system, 77.95% carbon ratio and 8064 K.cal/g calorie. Hatipoğlu et al. (2012) reported that its chemical analysis consists of C (94.2%), H (0.2%), O (3.3%), N (0.3%) and S (2.2%). According to the study presented by Karayiğit (2007), major element data in the Oltutaşi sample is as follows: Al (0.08%), Ca (0.18%), Na (0.08%), K (0.03%), Mg (0.01%), Ti (0.07%), P (0.01%), Fe (0.32%) and Mn (0.002%). These values are very low due to low ash content. However, slightly high Fe content in conjunction with the mineralogical data is related to the pyrite determined in the sample. It was also noted that the trace elements were probably linked with either organic matter or micron-sized minerals or both.

MINERALOGICAL PROPERTIES

The XRD results are illustrated in the Figures 5 and 6 for the samples of Oltutaşi and Oltutaşi-bearing deposit, respectively. It was observed from these figures that Oltutaşi sample includes abundant carbon organic (amorphous) matter and the other trace matters, such as, siderite and pyrite minerals (Figure 5). Meanwhile, Oltutaşi-bearing deposits are composed of the sandstone and siltstone alternation contains quartz, kaolinite, calcite and accessory pyrite (Figure 6). In the some scientific papers published on the Oltutaşi, it was mentioned that this natural material consists of abundant organic (amorphous) matter and trace amounts of quartz and pyrite that generally finely disseminated the organic matter (Çiftçi et al., 2004; Karayiğit, 2007; King, 2006; Hatipoğlu et al., 2012). Amber-bearing deposits are associated with lignite layers and some macroscopic and microscopic organic particles (Delclos et al., 2007). The lignites are known to contain fossil resins as the maceral resinite (Pipatmanomai et al., 2001). Macerals are the microscopically identifiable components in lignites (Stopes, 1935) and may be differentiated on the basis of morphology, reflectance, size and polishing relief. Maceral categories counted included total vitrinite, total liptinite and inertinite macerals, such as fusinite, semifusinite and micrinite (Rimmer et al., 2006).

The polished cross-section studies were carried out to identify the components of Oltutaşi. It observes from microphotographs that Oltutaşi includes dominantly carbon organic (amorphous) matter (Figure 7a to d) and it includes resinite, semifusinite (Figure 7a) and fusinite (Figure 7d). Also, textinite, corpohuminite and lipto-detrinite were observed by Karayiğit (2007) as maceral types. There are euhedral pyrite (Figure 7b) and hematite (Figure 7c) minerals observed from microphotographs. Pyrite minerals were probably developed in syngenetic formation related to carbone reducing environment. However, hematite formation could be a yield of pyrite oxidation. Pyrite has partially replaced some organic inclusions, but also occurs as fracture fillings and rarely as isolated crystals. The occurrence of pyrite commensurates with reducing conditions in the tidal channel and indicates that some inclusions extended outside the amber or that sulfidic waters penetrated amber through fine fractures (Grimaldi et al., 2000).

EXTRACTING AND PROCESSING

The Oltutaşi is heavily extracted from the geological unit outcropped on the slopes of Yasak Mountain (Dutlu Village of Oltu), Northern Oltu. The location process for the Oltutaşi extracting gallery is carried out based on experience with field observations. The circumstantial evidence of Oltutaşi and lignite levels on the outcrops of Oltutaşi-bearing deposits is the key parameter for gallery site selection (Figure 8a). Oltutaşi is located in the lens form in the Oltutaşi-bearing deposits (Figure 8b). Its extracting is carried out by local peoples in the underground galleries with 70 to 130 cm diameters opened on the highland (Figure 8c). In these galleries, limited workers are employed changing between two and five persons from Dutlu Village. The Oltutaşi extracting galleries are created by using non-technological methods

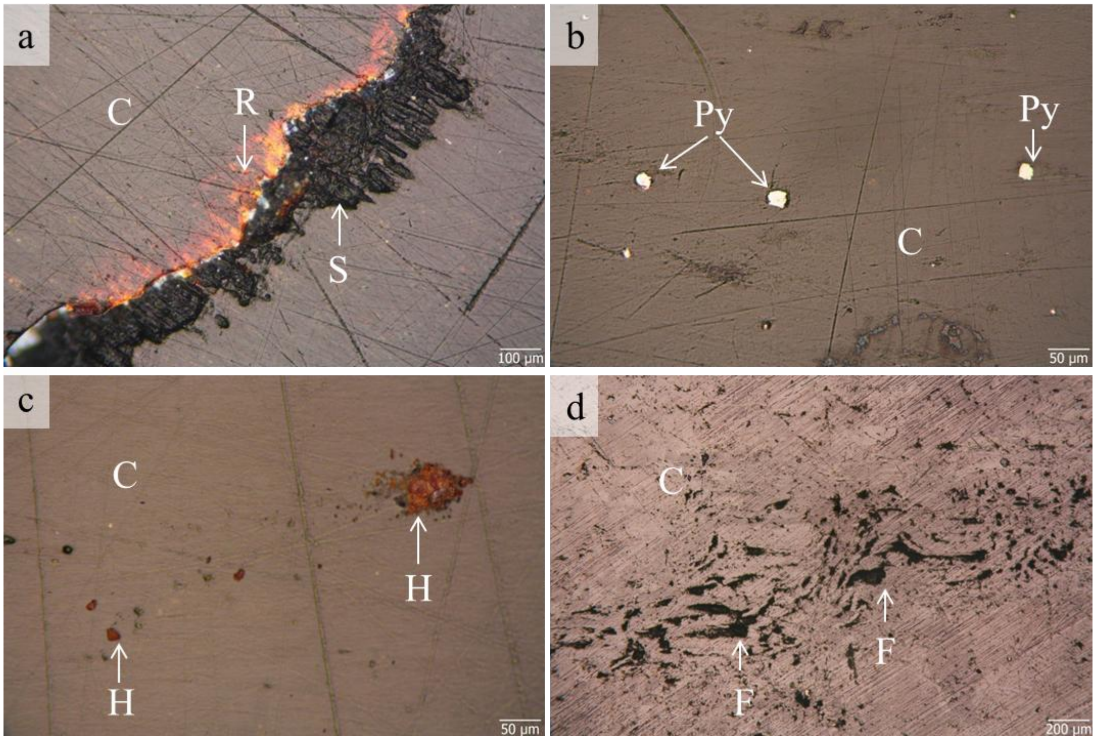

Figure 7. Some microphotographs from polished Oltutaşi samples; (a) Oltutaşi and its fracture filled with resinite and semifusinite, (b) Oltutaşi including euhedral pyrite, (c) Oltutaşi including hematite and (d) Oltutaşi including fusunite showing curved structure (C: carbone, R: resinite, S: semifusinite, H: hematite, Py: pyrite and F: fusinite).

(Bilgin et al., 2011). Some basic apparatus, such as digging, short-handled shovel, hammer and chisel are used for the gallery creating process (Figure 8d). When galleries continue to progress, the generated waste material are brought out from galleries by using transport tools with four-wheeled wooden which can be pulled by rope (Figure 8c). When the galleries reach up to 150 m or unexpected situations occur preventing it to work in the gallery, it is abandoned.

The raw Oltutaşi is processed by local artisans using some basic equipment, such as, electric lathe, polishing wheel, drill and some hand tools, such as, steel knife, file, sandpaper and turned suitable for working. The Oltutaşi is cut or carved in desired form and polished to manufacture rosery and various decorative ornaments and utensils like rings, earrings, necklaces, bracelets, tie pins, smoking pipes, cigarette holders and prayer beads (Figure 9a and b).

CONCLUSIONS

Turkish black amber named Oltutaşi in Turkey is one of the best examples of semi-precious stone to be found in the world. The Oltutaşi-bearing deposits lie at approximately 130 km Erzurum and are located in the Eastern Pontide belt, which forms the basement, and occupies a broad belt parallel to the coast of the Black Sea. It was found in the aged Jurassic-Cretaceous geological sedimentary units outcropping study area. Oltutaşi is mainly extracted in the county of Oltu (Erzurum) and surrounding mountains. Although, Oltutaşi is soft when first exploited, becomes harder as it is carved by contacting with air and it gets glossy as long as it is used. An Oltutaşi sample includes abundant carbon organic matter and the other trace matters, such as, siderite and pyrite minerals. Meanwhile, Oltutaşi-bearing deposits are composed of the sandstone and siltstone alternation contains quartz, kaolinite, calcite and accessory pyrite. Its production is carried out by non-technological methods in the underground galleries and is processed by local artisans to convert into valuable products.

ACKNOWLEDGEMENTS

The laboratory study of this research was carried out in the Laboratories of Karadeniz Technical University and Ataturk University. So, the authors thank the authorities of these universities. The authors thank the workers of Oltutaşi extracting for assistance during the field work. They are also deeply grateful to anonymous reviewers for their helpful comments on the manuscript.

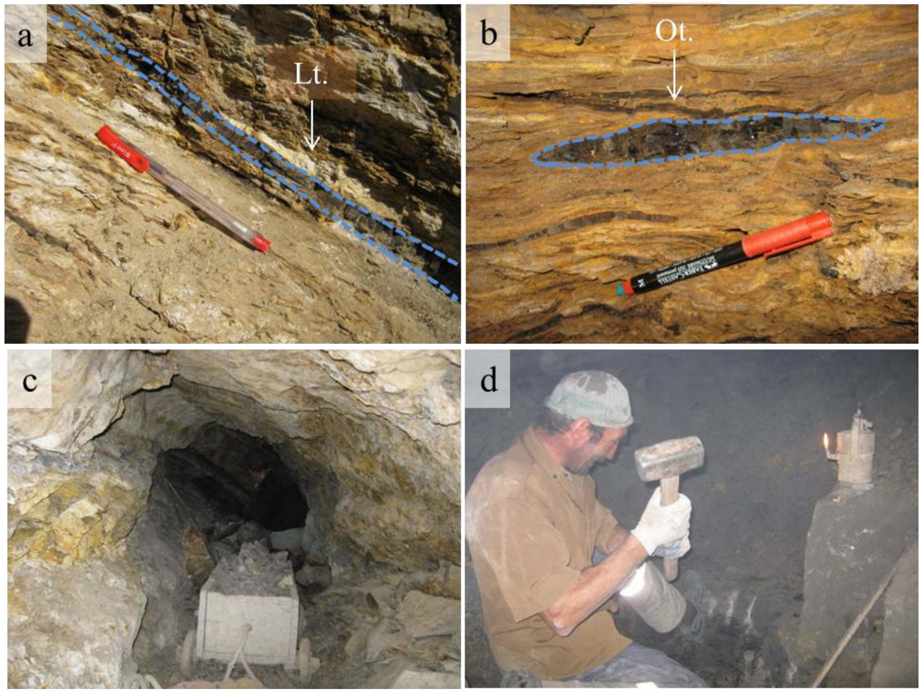

Figure 8. Some photographs; (a) Oltutaşi-bearing deposits outcrop including lignite layer being circumstantial evidence of Oltutaşi, (b) Oltutaşi-bearing deposits including v lenses in the gallery, (c) gallery extracted Oltutaşi and transport tool in gallery for waste material disposal and (d) local worker extracting the Oltutaşi in the gallery (Ot: Oltutaşi lens, Lt: lignite).

Figure 9. Some photographs; (a) raw Oltutaşi samples and rosary produced from Oltutaşi, and (b) rosary and necklace produced from Oltutaşi.

REFERENCES

Alekseeva IA, Samarina LA (1966). The question of the chemical structure of amber. Khimiya Prirodnykh Soedinenii, (2)6: 429-436.

Alonso J, Arillo A, Barron E, Corral JC, Grimalt J, Lopez JF, Lopez R, Martinez-Delclos X, Ortuno V, Penalver E, Trincao PR (2000). A new fossil resin with biological inclusions in Lower Cretaceous deposits from Alava (northen Spain, Basque-Cantabrian Basin). J. Paleontology 74: 158-178.

Anderson KB, Crelling JC (1995). Amber, resinite and fossil resins. American Chemical Society.

Azar D (2007). Preservation and accumulation of biological inclusions in Lebanese amber and their significance. Comptes Rendus Palevol., 6: 151-156.

Baykal F (1950). Geological main lines of Oltu- Göle-Ardahan- Çıldır region. MTA report No: 1928 (in Turkish).

Bilgin Ö, Kalkan E, Dilmaç MK (2011). Equipments used for production and processing of Oltustone. The proccedings of 3rd Mining Machinery Symosium, May 05-06, İzmir, Turkey (in Turkish).

Bozkuş C (1991). Northeast stratigraphy of Oltu-Narman Tertiary Basin. Bulletin of TJK 33, 47-66 (in Turkish).

Boztuğ D, Jonckheere R, Wagner GA, Yeğingil Z (2004). Slow Senonian and fast palaeocene-early eocene uplift of granitoids in the central eastern Pontides Turkey: apatite fission-track results. Tectonophysics 382(3-4): 213-228.

Brouwer SB, Brouwer PA (1982). Geologia de la region ambarifera oriental de la Republica Dominicana. Trans. 9th Caribbean Geol. Conf., Santo Domingo 1: 305-322.

Buchberger W, Falk H, Katzmayr MU, Richter AE (1997). On the chemistry of baltic amber inclusion droplets. Monatshefte für Chemie-Chemical Monthly, 128: 177-181.

Bulut A, Ogen Y, Demirci S, Bozkuş C, Taka M, Oner A (1984). Detailed geological investigation Tortum-Narman-Oltu-Olur (Erzurum) and surrounding area (in Turkish). MTA report No: 8889.

Canıtez N, Toksöz MN (1980). Crustal structure beneath Turkey. EOS Trans. Am. Geophys. Union 61(17): 290.

Carlsen L, Feldthus A, Klarskov T, Shedrinsky A (1987). Geographical classification of amber based on pyrolysisand infra-red spectroscopy data. J. Analytical Appl. Pyrolysis, 43: 71-81.

Cruickshank RD, Ko K (2003). Geology of an amber locality in the Hukawng Valley, northern Myanmar. J. Asian Earth Sci., 21: 441-455.

Çiftçi E, Coşkun S, Yalçınalp B (2002). Oltustone-mineralogical and physical properties. 55th Geological Congress of Turkey, March 11-15, Ankara, Turkey.

Çiftçi E, Yalçin MG, Yalçınalp B, Kolaylı H (2004). Mineralogical and physical characterization of the Oltustone, a gemstone occurring around Oltu (Erzurum-Eastern Turkey). International Congress on Applied Mineralogy (ICAM 2004), September 19-22, Brazil.

Delclos X, Arillo A, Penalver E, Barron E, Soriano C, Lopez R, Bernardez E, Corral C, Ortuno VM (2007). Fossiliferous amber deposits from the Cretaceous (Albian) of Spain. Comptes Rendus Palevol, 6: 135-149.

Dewey JF, Hempton MR, Kidd WSF, Şarolu F, Şengör AMC (1986). Shortening of continental lithosphere: the neotectonics of Eastern Anatolia-a young collision zone. In: Coward, M.P., Ries, A.C. (Eds.), Collision Tectonics. Geol. Soc. London, Spec. Publ., pp. 3-36.

Dönmez M, Işık I (1999). Stratigraphy and Mineralogy of Oltu (Erzurum) Stone beds. Sciences J. Dumlupınar University, 1: 281-295.

Eberle W, Hirdes W, Muff R, Pelaez M (1982). The geology of the Cordillera Septentrional (Dominican Republic). Trans. 9th Caribbean Geol. Conf., Santo Domingo 1: 619-632.

Erentöz C (1954). Geology of Aras basin. The Bulletin of Turkey Geology General Meeting. 5: 1-53.

Ethem MY (1990). Precious Stones and semiprecious Stones from A to Z. Mars Production, Ankara (in Turkish).

Franks PC (1980). Models of marine transgression-example from Lower Cretaceous fluvial and paralic deposits, north-central Kansas. Geology, 8(1): 56-61.

Gattinger TE (1955). Geological mapping studies between Çoruh and Erzurum in the Northeast Turkey. MTA report No: 2379.

Girard V, Schmidt AR, Saint Martin S, Struwe S, Perrichot V, Saint Martin JP, Grosheny D, Breton G, Neraudeau D (2008). Evidence for marine microfossils from amber. Proc. Natl Acad Sci., 105: 17426-17429.

Gomez B, Martinez-Delclos X, Bamford M, Philippe M (2002). Taphonomy and palaeocology of plant remains from the oldest African Early Cretaceous amber locality. Lethaia 35: 300-308.

Grimaldi D (1996). Amber: Window to the Past. New York: Abrams/AMNH.

Grimaldi DA, Engel MS, Nascimbene PC (2002). Fossiliferous Cretaceous amber from Myanmar (Burma): its rediscovery, biotic diversity, and paleontological significance. American Museum Novitates 3361: 1-72.

Grimaldi DA, Shedrinsky A, Wampler TP (2000). A remarkable deposit of fossiliferous amber from the Upper Cretaceous (Turonian) of New Jersey. In: Grimaldi, D.A. (Ed.), Studies of Amber, with Particular Reference to the Cretaceous of New Jersey. Backhuys Publishers, Leiden.

Hamamoto T, Horikoshi K (1994). Characterization of a bacterium isolated from amber. Biodaversity and Conservation 3: 567-572.

Hatipoğlu MD, Ajo, Kibici Y, Daniele P (2012). Natural carbon black (Oltu-stone) from Turkey: a micro-Raman study. Neues Jahrbuch für Mineralogie - Abhandlungen. 189(1): 97-101.

Iturralde-Vient MA (2001). Geology of the amber-bearing deposits of the Greater Antilles. Caribbean J. Sci., 37: 141-167.

Iturralde-Vinent MA, Hartstein E (1998). Miocene amber and lignitic deposits in Puerto Rico. Caribbean J. Sci., 34: 308-312.

Iturralde-Vinent MA, MacPhee RDE (1996). Age and paleogeographical origin of Dominican amber. Sci., 273: 1250-1252.

Kalkan E (2003). The improvement of geotechnical properties of Oltu (Erzurum) clayey deposits for using them as barriers. PhD Thesis (in Turkish), Ataturk University, Graduate School of Natural and Applied Science, Erzurum, Turkey. p. 135

Kalkan E, Bayraktutan MS (2008). Geotechnical evaluation of Turkish clay deposits: a case study in Northern Turkey. Environmental Geology, 55: 937-950.

Karayigit AI (2007). Origin and properties of Oltu Gemstone coal. Energy Sources, Part A, 29: 1279-1284.

Keskin M (2003). Magma generation by slab steepening and breakoff beneath a subductioneaccretion complex: an alternative model for collisionrelated volcanism in Eastern Anatolia, Turkey. Geophys. Res. Lett., 30: 8046.

Keskin M, Pearce JA, Mitchell JG (1998). Volcano-stratigraphy and geochemistry of collision-related volcanism on the Erzurum-Kars Plateau, northeastern Turkey. J. Volcanol. Geotherm. Res., 85: 355-404.

King RJ (2006). Minerals Explained 44: Amber (Part 1). Geology Today. (22)6: 232-237.

Kocyigit A, Öztürk A, İnan S, Gürsoy H (1985). Tectonomorphology and mechanistic interpretation of the Karasu Basin (Erzurum). Bull. Earth Sci., 2: 3-15.

Koçyiğit A, Rojay B (1984). New tectonic framework of East Anatolian Region and Horosan- Narman (Erzurum) eartquake - 1983. Proceedings of First National Eartquake Symposium, Atatürk University, Erzurum, Turkey, 248-265.

Konak N, Hakyemez Y (2008). Geological mab of Turkey in scale 1: 100.000, Tortum H47 sheet (in Turkish). MTA publication, p. 95, Ankara.

Konak N, Hakyemez Y, Bilgiç T, Bilgin R, Hepşen N, Ercan T (2001). Northeast Pontides (Oltu-Olur-Şenkaya-Narman-Tortum-Uzundere-Yusufeli) Geology (in Turkish). MTA report. No: 10089.

Knight TK, Bingham PS, Grimaldi DA, Anderson K, Lewis RD, Savrda CE (2010). A new Upper Cretaceous (Santonian) amber deposit from the Eutaw Formation of eastern Alabama, USA. Cretaceous Res., 31: 85-93.

Langenheim JH (1969). Amber: a botanical inquiry. Science, 163: 1157-1169.

Langenheim JH (1990). Plant resins. Am. Sci., 78: 16-24.

Lahn E (1939). Geological investigation of an area between Karasu and Çoruh, NE Turkey. MTA report No: 838, Ankara (in Turkish).

Lee YT, Langenheim JH (1975). Systematics of the genus *Hymenaea* L. (*Leguminosae, Caesalpinioideae, Detarieae*). University of California Publications in Botany. 69: 1-120.

Martinez-Delclos X, Briggs DEG, Penalver E (2004). Taphonomy of insects in carbonates and amber. Palaeogeography, Palaeoclimatology, Palaeoecology. 203: 19-64.

Mills JS, White R, Cough LJ (1984). The chemical composition of Baltic amber. Chemical Geology, 47: 15-39.

Mills JS, White R (1999). The organic chemistry of museum objects. 2nd edition. Butterworth-Heinemann. p. 206.

Nebert K (1964). Geology of Oltu (Erzurum) Oligocene deposits. MTA publication. p.32.

Nel A, Perrault G, Perrichot V, Neraudeau D (2004). The oldest ant in the Lower Cretaceous amber of Charent-Maritime (SW France) (Insecta: *Hymenoptera: Formicidae*). Geologica Acta. 2: 23-29.

Nissenbaum A, Horowitz A (1992). The Levantine amber belt. J. Afr. Earth Sci., 14: 295-300.

Otto A, Wilde V (2001). Sesqui-, di-, and triterpenoids as chemosystematic markers in extant conifers - a review. Bot. Rev., 67: 141-238.

Parlak T (2001). Oltu Stone and Jevelry Art in the Erzurum. Published by Development of Oltu Stone Art, Protection of Artisans and Improvement Association Cheirmanship, Oltu-Erzurum, Turkey, pp. 103 (in Turkish).

Pastorelli G (2009). Archaeologıcal Baltic amber: degradation mechanisms and conservation measures. PhD Thesis. University of Bologna. Italy. p. 194.

Pearce JA, Bender JF, De Long SE, Kidd WSF, Low PJ, Güner Y, Şaroğlu F, Yılmaz Y, Moorbath S, Mitchell JG (1990). Genesis of collision volcanism in Eastern Anatolia, Turkey. J. Volcanol. Geotherm. Res., 44: 189-229.

Penalver E, Delclos X, Soriano C (2007). A new rich amber outcrop with palaeobiological inclusions in the Lower Cretaceous of Spain. Cretaceous Res., 28: 791-802.

Penney D, Selden PA (2006). First fossil Huttoniidae (Arthropod: Chelicerata: Araneae) in late Cretaceous Canadian amber. Cretaceous Res., 27: 442-446.

Pipatmanomai S, Islas CA, Suelves I, Herod AA, Dugwell DR, Kandiyoti

R (2001). Pyrolysis of Baltic amber in a wire-mesh pyrolysis reactor: structural comparison of the tars with amber extracts in NMP. J. Analytical Appl. Pyrolysis, 58-59: 299-313.

Poinar GO (1991). *Hymenaea protera* sp. n. (*Leguminosae, Caesalpinioideae*) from Dominican amber has african affinities. Experientia. 47:1075-1082.

Poinar GO, Milki R (2001). Lebanese Amber: The Oldest Insect Ecosystem in Fossilized Resin. Oregon State University Press, Corvallis, p. 96.

Poinar G, Poinar R (1999). The Amber Forest. A Reconstruction of a Vanished World, Princeton University Press, Princeton, NJ, USA. Caribbean Geol. Conf., Santo Domingo. 1: 199-210.

Redmond B (1982). The Tertiary of the Central Cordillera Septentrional. Trans. 9th Caribbean Geol. Conf., Santo Domingo 1: 199-210.

Rice PC (1999). Amber the golden gem of the ages. NY: Kosciuszko Foundation, Inc.

Rimmer SM, Rowe HD, Taulbee DT, Hower JC (2006). Influence of maceral content on $\delta^{13}C$ and $\delta^{15}N$ in a Middle Pennsylvanian coal. Chem. Geol., 225: 77- 90.

Ross A (1998). Amber: the natural time capsule. Natural History Museum Publishing. p. 73.

Savkevich SS (1981). Physical methods used to determine the geological origin of amber and other fossil resins: some critical remarks. Physics and Chemistry of Minerals. 7: 1-4.

Schlee D (1990). Besonderheiten des Dominikanischen Bernsteins. Stuttgart Beitr. Naturk. 18: 63-71.

Stopes MC (1935). On the petrology of banded bituminous coal. Fuel. 14: 4-13.

Şengör AMC, Kidd WSF (1979). Post-collisional tectonics of the Turkish-Iranian plateau and a comparison with Tibet. Tectonophysics. 55: 361-376.

Şengör AMC, Yılmaz Y (1981). Tethyan evolution of Turkey: a plate tectonic approach. Tectonophys., 75: 181-241.

Şengör AMC, Özeren S, Genç T, Zor E (2003). East Anatolian high plateau as a mantle supported, northesouth shortened domal structure. Geophys. Res. Lett., 30(24): 8045.

Şengör AMC, Görür N, Şaroğlu F (1985). Strike-slip faulting and related basin formation in zones of tectonic escape. Turkey as a case study. In: Strike-Slip Deformation, Basin Formation and Sedimentation. SEMP Special Publications. 37: 227-264.

Şengör AMC, Özeren MS, Keskin M, Sakınç M, Özbakır AD, Kayan I (2008). Eastern Turkish high plateau as a small Turkic-type orogen: implications for post-collisional crust-forming processes in Turkic-type orogens. Earth Sci Rev., 90: 1-48.

Tyson RV (1995). Sedimentary organic matter: Organic facies and palynofacies. Chapman and Hall, London.

Urbanski T, Molak W (1984). Chemistry of Baltic amber: part VII. Bulletin of the Polish Academy of Sciences, Chem., 32: 3-7.

Van den Bold W (1988). Neogene paleontology in the northern Dominican Republic: 7. The subclass *Ostracoda* (*Arthropoda: Crustacea*). Bull. Am. Paleontol. 94 (329): 1-79.

Yılmaz H (1985). Geology of Olur (Erzurum) region (in Turkish). Earth Sciences J. Karadeniz Technical University, 4: 23-41.

Yılmaz S, Boztuğ D (1996). Space and time relations of three plutonic phases in the Eastern Pontides (Turkey). Int. Geol. Rev., 38: 935-956.

Zengin Y (1956). Oltu taşı beds. Bulletin of MTA (Turkey). 48: 148-149 (in Turkish).